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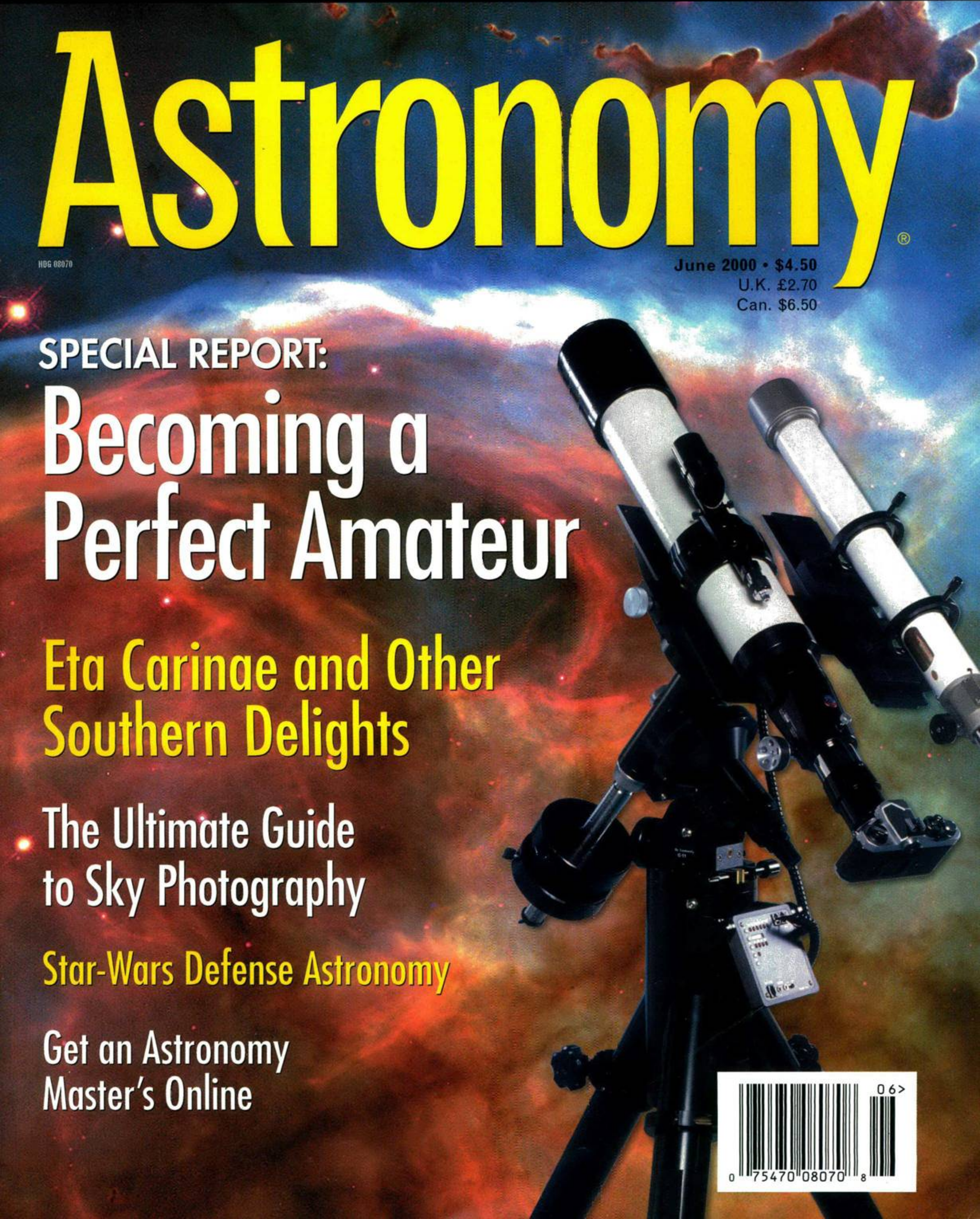

SPECIAL REPORT:

Becoming a Perfect Amateur

Eta Carinae and Other Southern Delights

The Ultimate Guide to Sky Photography

Star-Wars Defense Astronomy

Get an Astronomy Master's Online

New Low Prices!

MEADE

LX200

8" LX200

$2295

10" LX200

$2695

12" LX200

$3995

The largest-selling serious telescopes in the world are now available at the most affordable prices *ever!*

The exact same LX200's as before: not one specification has been changed. **Compare a Meade LX200 feature-for-feature with competing single-tine-fork, spur-gear-driven, GO TO Schmidt-Cassegrains.** You'll see why there really is no comparision:

- **Superb Optics:** With oversize primary mirrors for greater full-field illumination, LX200 diffraction-limited imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Competing 8" Schmidt-Cassegrains claim to place objects "somewhere in the field of view;" Meade LX200's place objects **dead-center** in the field of view, first time, every time, to a pointing precision of **2 arc-minutes or better,** or, with Meade-exclusive High Precision Pointing, to a precision of **one arc-minute or better.** *Meade LX200's are the only commercial telescopes ever manufactured that automatically GO TO any input R.A. and Dec., or to any object in the onboard database, to these levels of precision.*
- **Database of 64,359 Objects,** a database *more than three times larger* than competing GO TO telescopes.
- **Permanently-Programmable Smart Drive™** routinely achieves 5 arc-sec. periodic error, an observatory standard. Competing GO TO 8" SCT's decline to state their periodic error and do not offer any programmable error-corrector.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every contingency of telescope posi-

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MEADE LX200 EMC
MEADE LX200
SMART DRIVE
Meade
ENTER
MODE
GO TO
N
W
E
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Meade 8" LX200 Schmidt-Cassegrain Telescope — now $2295, complete.

tioning — from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between. Competing 8" SCT's slew only up to 6.5°/sec.

■ **Rigid LX200 Dual-Tine Fork Mountings with Dual 5.75" Worm Gears** are the choice of advanced observers, CCD imagers, and astrophotographers for their most sensitive applications. Competing spur-gear-driven single-tine forks can not approach the strength, rigidity, and drive-rate precision built into every Meade LX200 mounting.

■ **Full Long-Exposure Capability:** Competing 8" GO TO telescopes describe their capability to take short-exposure "planetary and terrestrial photos," without reference to any long-exposure capabilities. Meade LX200's have been the instruments of choice in **thousands** of the most detailed long-exposure images ever taken by amateur astronomers.

■ **Strong Field Tripods:** Unlike the thin, extruded aluminum tripods of competing models, every LX200 includes a fully adjustable steel field tripod perfectly suited to the sub-arc-second resolution of the telescope's optics.

"...Viewing a 2nd-magnitude star at high power [the 8" LX200] showed a nearly textbook-perfect image...I do indeed rank these optics as diffraction limited...Jupiter and Saturn exhibited riveting detail... During the November 10, 1997, triple shadow transit on Jupiter, the LX200 was my telescope of choice. It showed all three moon shadows as plainly different in size and shading, a rare and remarkable sight. Under the automatic GO TO command, the LX200 routinely placed objects, including the Moon and planets, within 1 to 4 arc-minutes of the center of the field. Not only was it accurate — it was fast. The LX200 usually took no longer than 10 to 25 seconds to slew to and center an object...The latest major feature added to the system is what Meade calls High Precision Pointing. When this is activated...Meade promises a pointing accuracy of 1 arc-minute. I can confirm this amazing figure. Objects consistently ended up within 1 to 2 arc-minutes of the field's center, a great aid to CCD imaging of faint targets...if you know what you want to look at, the LX200 will find it with astonishing speed and accuracy...the telescope I tested provided excellent performance in all critical areas while adding a level of technical luxury that is truly powerful and impressive...I have absolutely no hesitation in recommending the LX200 series...After having used the LX200 for several months, I can attest to the wonderful hands-off convenience and sheer fun of the motorized GO TO." — **from the review in *Sky & Telescope*, April, 1998.**

"The [10" LX200] telescope's optics, stability, and tracking accuracy — all of which are crucial in my applications — are truly remarkable, fully up to the demands that my photographic program requires. My LX200 is now nearly four years old, and during that time it has received heavy use, including 2000-mile round trips to southern France four times a year. The telescope is everything I could possibly have expected it to be." — **Philip Perkins, Wiltshire, England**

The Whirlpool Galaxy (M51) in Canes Venatici.
A 10" LX200 photo by Philip Perkins; two 120-minute exposures were digitally combined to obtain the final image.

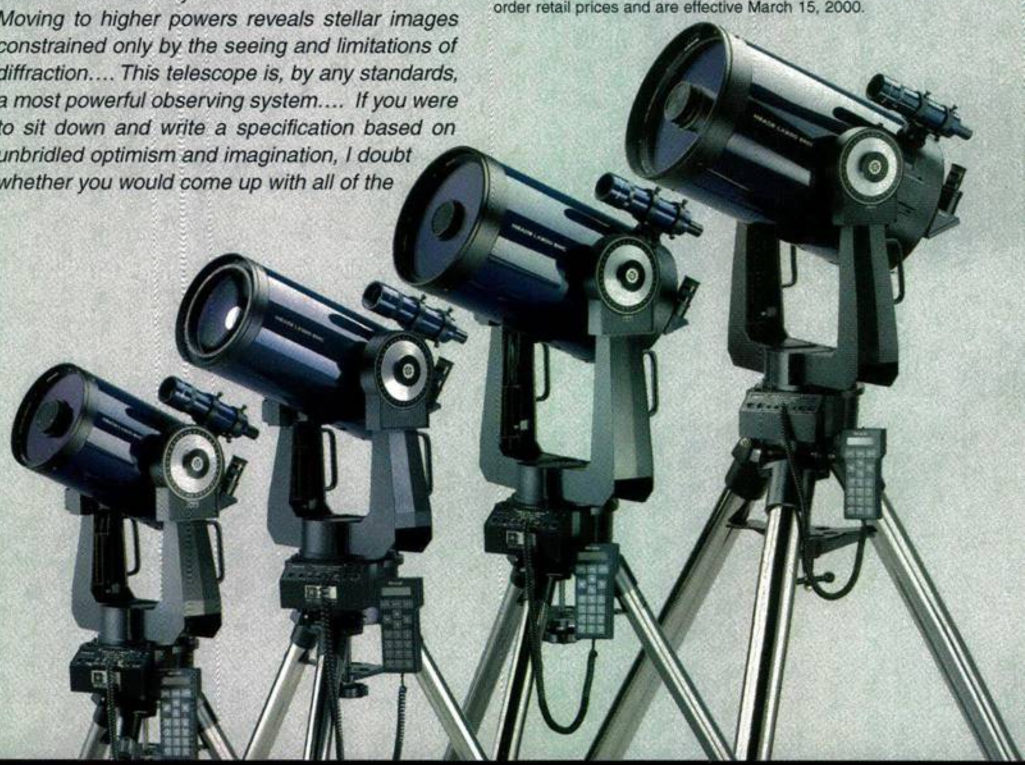
"The view through the [7" LX200] system is superb, with pin sharp images right across the field and absolutely no trace of achromatism. Moving to higher powers reveals stellar images constrained only by the seeing and limitations of diffraction.... This telescope is, by any standards, a most powerful observing system.... If you were to sit down and write a specification based on unbridled optimism and imagination, I doubt whether you would come up with all of the features available on the LX200 series. This telescope really has to be experienced." — **from the review in *Astronomy Now* (U.K.), November, 1996, by Bob Neville, Director, Instruments and Imaging Section, British Astronomical Association.**

"The optics of my 12" LX200 are exquisite — in fact the best optics in a commercial catadioptric telescope that I have ever looked through. At 500X the Epsilon Lyrae double-double is not only clearly split into four components, but each of the four stars exhibits a textbook-perfect diffraction pattern, the ultimate test for superior optics." — **Jack Newton, Chiefland, FL.**

SPECIFICATIONS: 7", 8", 10", and 12" LX200's — Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC (optional #1812 Electronic DC Adapter allows for field powering directly from an automobile cigarette lighter plug); 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

8" LX200 Schmidt-Cassegrain	**$2295.**
10" LX200 Schmidt-Cassegrain	**2695.**
12" LX200 Schmidt-Cassegrain	**3995.**
7" LX200 Maksutov-Cassegrain	**2795.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125. Prices shown are suggested U.S. mail-order retail prices and are effective March 15, 2000.



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COVER PHOTOS: Hubble Heritage Team (NASA/STScI/AURA); inset: *Astronomy*

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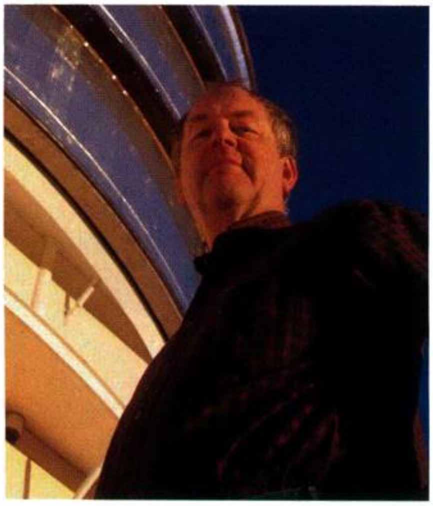

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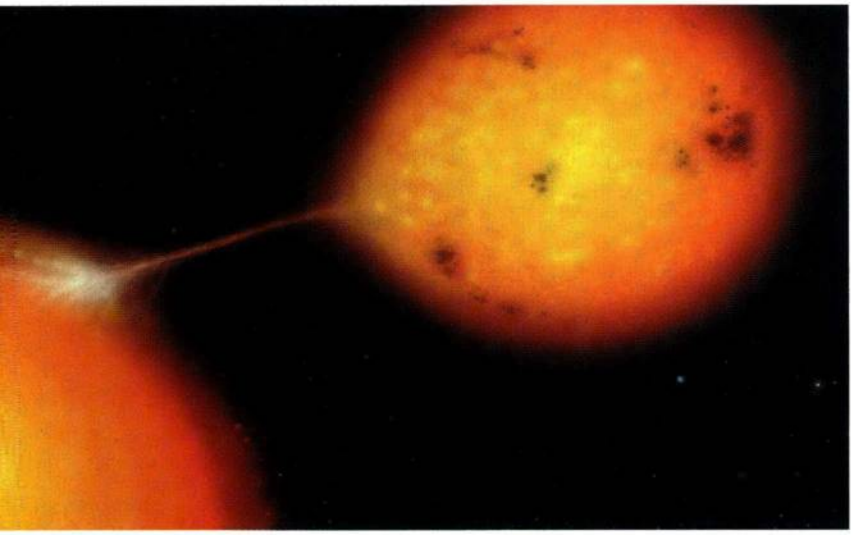

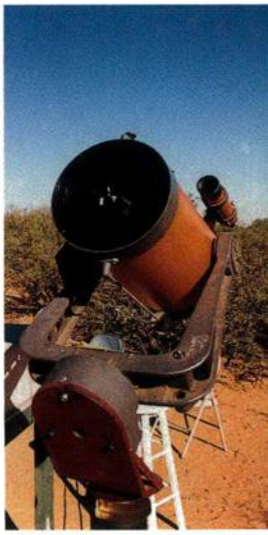

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BEHIND THE SCENES

BY BONNIE BILYEU GORDON

Comet LINEAR Comes to Yellowstone

If your idea of a summer vacation includes visiting Old Faithful by day and searching out the brightest comet of the year by night, consider joining *Astronomy* editors July 21 and 22 at Yellowstone National Park. The magazine will be hosting the Rocky Mountain High Star Party (weather permitting) under one of the darkest patches of night sky in North America. Our goal is to help people spot Comet LINEAR at its brightest, as it approaches the sun. Astronomers expect LINEAR to reach a naked-eye brightness of 4th magnitude at its July 25 perihelion. It will be streaking through Ursa Major and Leo in late July.

Astronomy is cohosting the event with park rangers, the Museum of the Rockies, and a team of amateur astronomers from Montana. For Yellowstone, Judy Knuth Folts of the park's division of interpretation led the effort to bring this unique program to the park.

Yellowstone National Park

Old Faithful

Astronomy editors Rex Graham and Richard Talcott will present talks on comets at Old Faithful on July 21 and 22 and at Mammoth Hot Springs on July 22. Jim Manning, director of the Taylor Planetarium at the Museum of the Rockies in Bozeman, and a group of his fellow Montana astronomers will provide telescopes for public star parties on both nights.

Coincidentally, in July the sun will be near the peak in its 11-year sunspot cycle, so the Montana amateurs also will provide daytime views of sunspots at Old Faithful and Mammoth Hot Springs. Solar activity also increases the odds of seeing an aurora. So, if LINEAR fizzles, vacationers can hope for a display of the northern lights.

Watch for news about other *Astronomy*-hosted star parties later this year: We will host one in California in August and one in Colorado in October. We hope to see you at both of these.

In this issue of *Astronomy*, we present an amateur's essential guide to photography and to the southern skies. In the center of the book, you will find a beautifully designed pullout poster of Messier objects, the brainchild of assistant art director Tom Ford. Managing editor Dave Eicher, the founding editor of *Deep Sky* magazine, helped Tom pull it together.

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8" LX10

8" LX10 DELUXE

The optical performance of a Meade 8" LX200 Schmidt-Cassegrain...for only *$995!*

8" LX10: For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *Standard-equipment includes:*

Super-Multi-Coated Optical System: The *exact same* multi-coated 8" Schmidt-Cassegrain optical tube assembly as more expensive Meade 8" LX50 and LX200 models. **Series 4000 SP26mm eyepiece:** Complements the exquisite imaging of Meade 8" SC optics. **Equatorial Fork Mounting:** The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power applications of the telescope, or for photographic or CCD imaging. **Cordless, DC-Powered Electronic Motor Drive:** With electronically-regulated DC servo motor for automatic *sidereal-rate* tracking; powered by four AA-size batteries that fit conveniently through the telescope's control panel; battery life is in excess of 50 hours. **Worm-Gear System:** The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging. **Hand Controller:** Essential for micro-guiding the telescope during long-exposure astrophotography, the LX10's pushbutton hand controller enables precise corrections in R.A. at 2x speed. With the optional electric Declination motor added to the telescope, the hand controller is functional at 2x speeds on both telescope axes.

SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4-pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); SP26mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions. **$995.** (+ $65 packing & shipping in the 48 states)

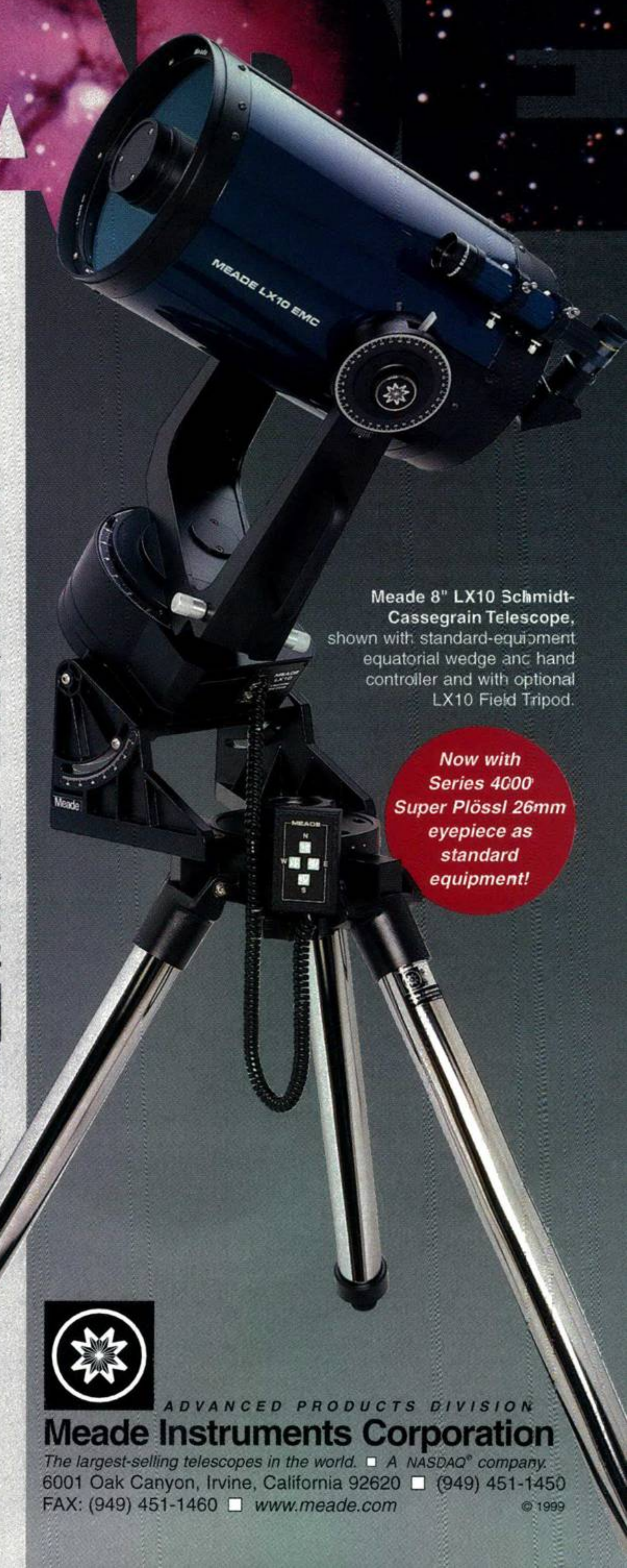
8" LX10 Deluxe: At only $1149 the 8" LX10 Deluxe includes (a) the large-aperture Meade #544 8 x 50mm viewfinder (in place of the standard 6 x 30mm finder); (b) the LX10 Electric Declination Motor System, permitting dual-axis guiding corrections at 2x speed; and (c) Meade Epoch 2000 Jr. Sky Software with 10,000-object database — all at substantially lower cost than if the respective accessories were purchased separately.

SPECIFICATIONS: 8" Model LX10 Deluxe — Identical in all specifications to 8" Model LX10, above, but with Electric Declination Motor System provided as standard equipment, permitting dual-axis corrections at 2x speed; Meade #544 8 x 50mm achromatic viewfinder in place of 6 x 30mm viewfinder; and Meade Epoch 2000 Jr. Sky Software with 10,000-object database.

$1149. (+ $65 packing & shipping in the 48 states)

Field Tripod for LX10 or LX10 Deluxe	195.
Electric Declination Motor System for LX10.....	95.
#2014 Magellan I Telescope Computer System for LX10 or LX10 Deluxe, with 12,218-object database	375.

The 120-page Meade General Catalog is available free of charge from Meade Instruments or from authorized Meade dealers.
Prices shown are suggested U.S. mail-order prices.



Meade 8" LX10 Schmidt-Cassegrain Telescope, shown with standard-equipment equatorial wedge and hand controller and with optional LX10 Field Tripod.

Now with Series 4000 Super Plössl 26mm eyepiece as standard equipment!

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Meade **ETX-90EC: $595** and **ETX-125EC: $895.** Each complete as shown, with electronic hand controller; plus packing and shipping.

Now two ETX apertures!
ETX-90EC — $595
ETX-125EC — $895

Now you can buy the revolutionary Meade ETX® — the largest selling modern telescope in the world — in either of two apertures, 3.5" or 5". Both models include the very latest in microprocessor-controlled capability.

New Fork Mount Designs with Standard-Equipment Dual-Axis Drive Systems: Each with high-torque DC motors on both telescope axes, permitting electronic operation from the standard-equipment plug-in hand controller.

Pushbutton Electronic Hand Controller: Use at any of four dual-axis speeds: 8x for image centering at high power; 32x for image centering at lower power or for pushbutton object-tracking in the altazimuth mode; 0.75°/sec for image centering in the viewfinder or for terrestrial tracking; 5°/sec for fast slewing across the sky.

Cordless Operation: The dual-axis drive system operates for more than 40 hours from eight (user-supplied) AA batteries which store neatly inside the drive base.

Optional Autostar™ Capability: Plug in the optional Meade Autostar computer controller *(see facing page)* for LX200-type operation, including automatic GO TO capability to more than 14,000 celestial objects.

Plus the features that created the ETX revolution:

Maksutov-Cassegrain Optical Systems: Manufactured at the Meade Irvine, California facility, ETX diffraction-limited optics produce images so high in contrast, brightness, and resolution that ETX telescopes often outperform other telescopes of larger apertures.

Flip-Mirror System: Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter.

SPECIFICATIONS: ETX-90EC and ETX-125EC Astro Telescopes — Each includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8 *or* D = 127mm, F = 1900mm, f/15) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; fork mount with electric slow-motion controls, setting circles and locks on both axes; electronic control panel; 4-speed (8x, 32x, 0.75°/sec, 5°/sec) dual-axis motor drive system with hand controller; sidereal-rate tracking in equatorial mode with optional table tripod or deluxe field tripod; internal battery compartment accepting eight (user-supplied) AA-size batteries; 8 x 21mm erect-image (ETX-90EC) *or* 8 x 25mm right-angle (ETX-125EC) viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); instructions. **ETX-90EC — $595** (+ $20 packing & shipping in the 48 states); **ETX-125EC — $895** (+ $30 P & S).

OPTIONAL SYSTEMS*

#497 Autostar Computer Controller (90, 125)	$149
#880 Equatorial Table-Tripod (90)	29.95
#881 Equatorial Table Tripod (125)	59.95
#883 Deluxe Field Tripod (90, 125)	199.95
#825 8 x 25mm Right-Angle Viewfinder (90)	49.95
#774 Hard Carry Case (90)	99.95
#775 Hard Carry Case (125)	149.95
#932 45° Erecting Prism (90, 125)	49.95
#64 Photo Adapter (90, 125)	34.95
Electric Focuser #1244 (90) *or* #1247 (125)	119.95

**see the Meade accessory ad in this issue.*

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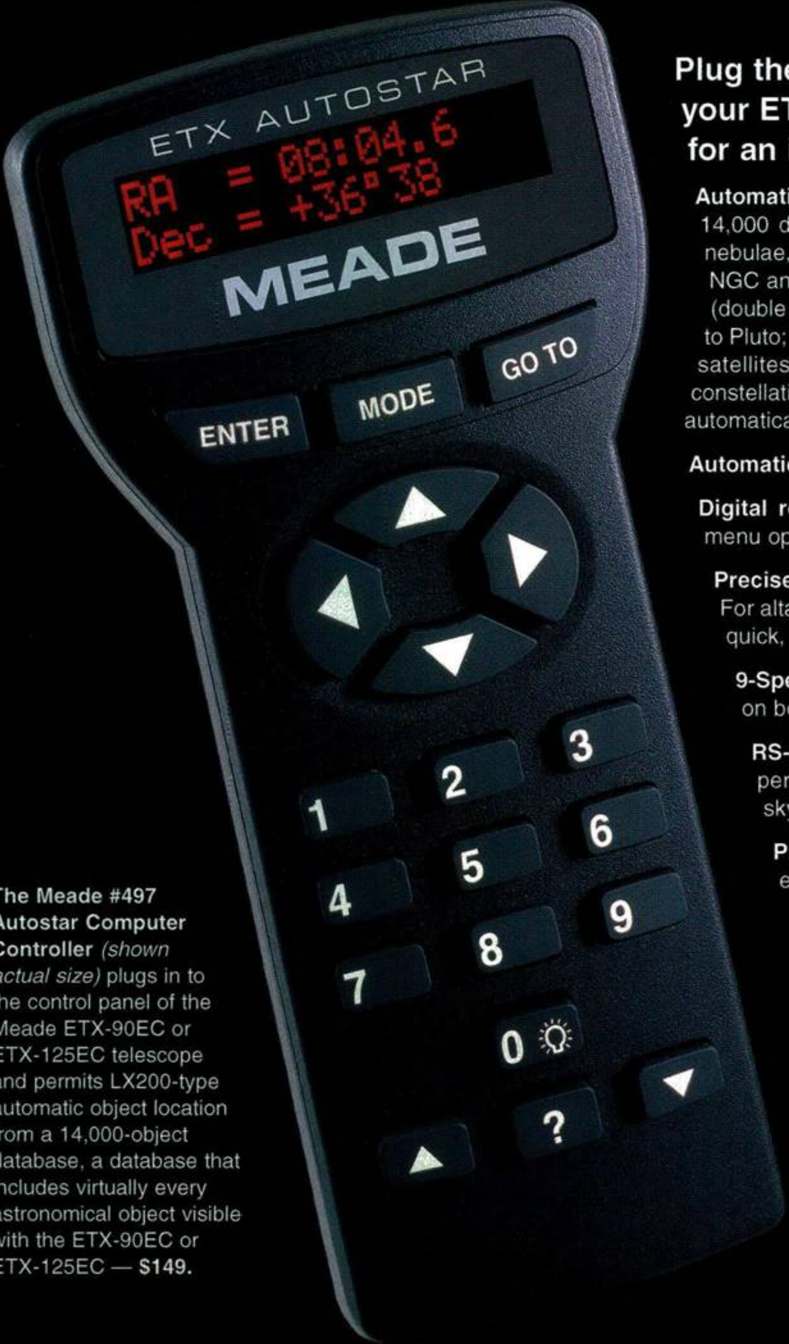
Add the Meade Autostar™ computer to your ETX-90EC or ETX-125EC for automatic GO TO object location ...only *$149!*



The Meade #497 Autostar Computer Controller *(shown actual size)* plugs in to the control panel of the Meade ETX-90EC or ETX-125EC telescope and permits LX200-type automatic object location from a 14,000-object database, a database that includes virtually every astronomical object visible with the ETX-90EC or ETX-125EC — **$149.**

Plug the #497 Autostar Computer Controller into your ETX-90EC or ETX-125EC and you're ready for an incredible array of LX200-type capabilities:

Automatic dual-axis GO TO function at 5°/sec to any of more than 14,000 database objects, including deep-space objects (galaxies, diffuse nebulae, planetary nebulae, star clusters — the best objects from the IC, NGC and Caldwell catalogs, as well as all 110 Messier objects); 900 stars (double stars, variable stars, SAO stars); the 8 major planets from Mercury to Pluto; 26 of the brightest asteroids; 15 periodic comets; 50 earth-orbiting satellites; plus user-defined objects and the centroids of all 88 constellations. Select any of these objects, press ***GO TO*** and the telescope automatically slews to the object, placing it in the telescopic field.

Automatic GO TO function to *any* object of known R.A. and Dec.

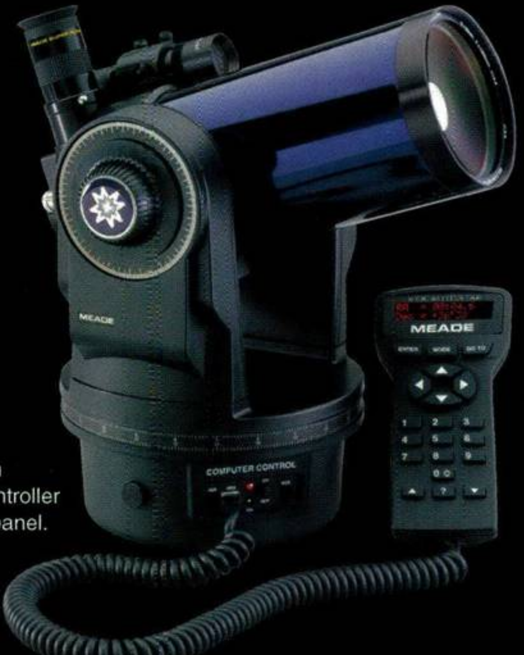
Digital readouts of telescope position (continuously in R.A. and Dec.), menu options, glossary, and utility functions.

Precise sidereal-rate tracking in either altazimuth or equatorial modes. For altazimuth tracking, set the telescope on its drive base and perform a quick, easy alignment.

9-Speed Dual-Axis Operation: Pushbutton operation of the telescope on both axes, simultaneously, at any speed from 2x sidereal to 5°/sec.

RS-232 Serial Port: For operation of the telescope through a personal computer, using Meade Epoch 2000® sky software or other sky software using the LX200 protocol.

Plus: over 20 other menu options, including guided tours, major event menus, user-defined terrestrial objects, and much more.



(right) **Meade ETX-90EC,** shown with optional #497 Autostar Computer Controller plugged into the telescope's control panel.

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Prices shown are suggested U.S. mail-order retail prices.
Patents pending on ETX-90EC, ETX-125EC, and Autostar.

New Low Prices!

MEADE STARFINDER™ DOBSONIANS & EQUATORIALS

Meade® Starfinder 10" Dobsonian ...*now only* *$449!*

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Complete with 1.25" rack-and-pinion focuser, 5 x 24mm viewfinder, Super Plössl 26mm eyepiece, and premium-grade Pyrex® optical system.

Shown with optional #2010 Magellan I Computer System.

The lowest prices *ever* for Meade Starfinder Dobsonians — complete with these standard features:

Series 4000 SP26mm Eyepiece (1.25"): This $80 eyepiece permits all Meade Starfinder Dobsonians to perform absolutely to their maximum capabilities.

Professional-Grade Optical System with hand-figured optics of Grade-A fine-annealed Pyrex glass, *unlike the plate glass optics of other Dobsonians that can become thermally unstable.* Optics are multi-coated and meet the theoretical limits of resolution.

Rigid, Durable, Beautiful Dobsonian Mountings: Zero-backlash Teflon/Nylon bearings facilitate the quick location and easy tracking of celestial objects with extremely smooth motions of the telescope in both altitude and azimuth.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: Strong, spiral-wound Sonotubes™ with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! Every Starfinder model opens up the skies to an extremely wide range of serious visual observing: all 110 *Messier objects, thousands of* NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets *in stunning high-resolution detail.* Starfinder Dobsonians are for visual observing; motor-driven Starfinder Equatorials may also be used for lunar and planetary photography, and even for limited deep-space photography.

Meade Starfinder Dobsonian Telescopes

Complete per specifications above:

6" f/8	**$249**	**10" f/4.5**	**449**
8" f/6	**349**	**12.5" f/4.8**	**795**
		16" f/4.5	**1195**

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

Dobsonian Deluxe Accessory Package...only $49.95!

Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

Meade #77 2" Giant Rack-and-Pinion Focuser, with eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. *(reg. $59.95)*

Meade #637 6 x 30mm Achromatic Viewfinder, with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*

Meade Series 4000 Super Plössl 9.7mm and 26mm multi-coated eyepieces — premium-grade eyepieces for high-resolution lunar, planetary, and deep-space observing. *(reg. $79.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $269.80!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes:

7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple. **#2010: for Meade Starfinder Dobsonian 6", 8", 10", 12.5", or 16" — $295.** Packing & shipping in the 48 states—$15.

Note: Many manufacturers compromise telescope performance by using low-cost plate glass — glass which can become thermally unstable — in their primary and secondary mirrors, or else they charge a premium for Pyrex optics. *Meade Starfinder Dobsonian and Equatorial telescopes include Pyrex glass, exclusively, at no additional cost.*

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STARFINDER MEADE

Meade® Starfinder 8" Equatorial with Motor Drive... *now only* ***$599!***

Complete with giant rack-and-pinion focuser for 1.25" and 2" eyepieces, 6 x 30mm viewfinder, Super Plössl 26mm eyepiece, and premium-grade Pyrex® optical system.

Shown with optional #2011 Magellan I Computer System.

Precision, heavy-duty equatorial mounts with DC-powered drive systems for fully automatic tracking.

Professional-Grade Optical System: Hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Accessories and Components: Premium-grade multi-coated SP26mm eyepiece (1.25"); 6 x 30mm viewfinder with wide 7° field; strong, durable, spiral-wound optical tube with attractive white finish.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System: For fully automatic tracking of celestial objects. Operates over 50 hours from 6 (user-supplied) AA-batteries or from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 1.25" and 2" eyepieces.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 giant focuser.

Magellan I Telescope Computer System: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page).*

#2011: for Meade Starfinder Equatorial 6", 8", or 10" . . . . . $295.
#2012: for Meade Starfinder Equatorial 16". . . . . 295.

Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

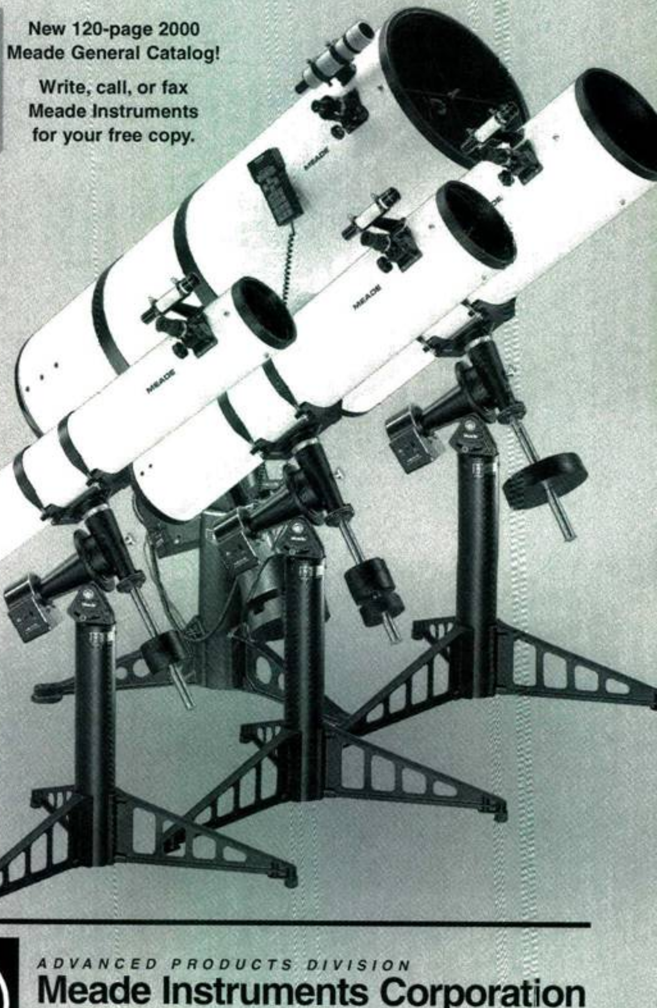
#2018: for Starfinder Equatorial 6", 8", 10" . . . . 495.
#2019: for Starfinder Equatorial 16" . . . . 595.

Packing & shipping in the 48 states: Magellan I – $15, Magellan II – $20.

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy a Meade Series 4000 Super Plössl 9.7mm eyepiece ***for only $29.95!*** *Purchased separately, the SP9.7mm eyepiece sells for $79.95.*

New 120-page 2000 Meade General Catalog!

Write, call, or fax Meade Instruments for your free copy.



Meade Starfinder Equatorial Telescopes

6" f/8	**$499**	**10" f/4.5**	**699**
8" f/6	**599**	**16" f/4.5**	**2695**

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

To Order any Starfinder model: contact your authorized Meade Advanced Products Dealer, below. Prices shown are suggested U.S.A. mail-order retail prices.

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 925-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 570-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders/Info: 800-621-2248; IL: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

ADVANCED PRODUCTS DIVISION
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The largest-selling telescopes in the world. ☐ *A NASDAQ company.*
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FAX: (949) 451-1460 ☐ *www.meade.com*

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MEADE RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm each: **$79.95** (4.54)

32mm (52°); **40mm** (44°) each: **99.95** (5.26)

56mm (52°; 2") **199.95** (7.02)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (5.26)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

f/6.3 FOCAL REDUCER/FIELD

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (4.54)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (4.54)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

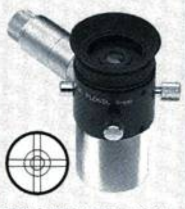
#929 or **#930**, each: **$99.95** (6.85)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.86)

World's Most Advanced Illuminated Reticle Eyepiece



Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A **49.95** (4.54)

Set #2–4 filters: #11, #25A, #47, #82A **49.95** (4.54)

Set #3–4 filters: #8, #21, #38A, #56 **49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

#1206 Electric Focuser: Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. **$149.95** (7.48)

#1205 Electric Focuser: For **all** other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

$169.95 (7.88)

#777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

$79.95 (6.85)

Series 3000™ Plössls 50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.86); **40mm** (44° field): **$79.95** (3.86)

#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia. **79.95** (4.54)

#910B–Threads into 2" eyepieces, 44mm dia. **119.95** (5.26)

#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **99.95** (5.26)

#908N–Threads into 1.25" eyepieces, 26mm dia. **89.95** (4.54)

#910N–Threads into 2" eyepieces, 44mm dia. **129.95** (5.26)

#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **119.95** (5.26)

#911X
#910X
#908X

Series 4000 Oxygen-III Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia. **99.95** (4.54)

#910X–Threads into 2" eyepieces, 44mm dia. **159.95** (5.26)

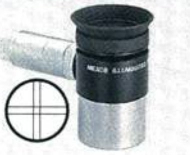
#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **149.95** (5.26)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (4.54)

MA12mm Illuminated Reticle Eyepiece



Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

$99.95 (3.45)

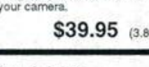
As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": **$27.95**; 1.25": **$29.95** (3.86)

Variable-Projection Camera Adapter (1.25")



Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (3.86)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (3.86)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (3.86)

CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with ***any*** brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope." — Jack Newton

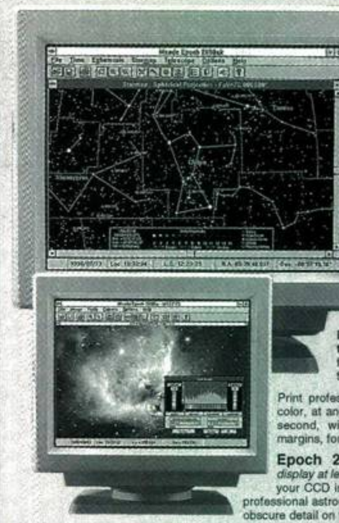
#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XT or ST-7, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XT, as well as ST-4 through ST-8; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)

#644
MEADE
FLIP-MIRROR SYSTEM

#647
MEADE
FLIP-MIRROR SYSTEM



Epoch 2000® Sky Software

The most powerful astronomical software ever made available can now be yours for only $149!

Epoch 2000sk *(upper display at left)*: Now you can use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** the Trapezium in Orion is no longer shown as a single point, as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Epoch 2000ip Image Processing Software *(lower display at left)*: Epoch 2000ip makes it easy to enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet. This powerful software includes virtually every technique available for image enhancement. Techniques that bring out detail totally invisible in your original image, transforming it from the ordinary to the spectacular.

EPOCH 2000sk Sky Software: 281,000 objects supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 . . . . . . **$149**

EPOCH 2000sk-CD Sky Software: 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM **179**

LX200 Interface Cable: for Meade LX200 operation by Epoch 2000sk **25**

EPOCH 2000ip Image Processing Software: Supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 . . . . . . **$199**

4000 f/3.3 CCD FOCAL REDUCER

Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

NEW!

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture. **$149.95** (5.26)

Plössl 25mm Illuminated Reticle CCD Framing Ocular

NEW!
MEADE
PLÖSSL
CCD FRAMING

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models and ST-4 through ST-8. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above)*. Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25". **$129.95** (4.54)

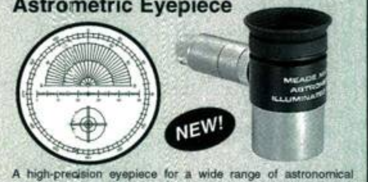
#825 8 x 25mm Right-Angle Viewfinder for ETX-90

Permits comfortable right-angle viewing. Replaces standard-equipment finder on 90mm ETX models, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helicoid focusing. **$49.95** (4.26)

#64 T-Adapter for ETX®

Threads to the photo port of all ETX-90 and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera. **$34.95** (3.86)

MA12mm Illuminated Reticle Astrometric Eyepiece



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For secure storage or travel with your ETX. Thick-wall construction and die-cut foam lining. Accepts telescope, plus optional eyepieces, erecting prism, table tripod, hand controller, *etc.* Includes two steel latches with key.

#774 Case for ETX-90 models: **99.95** (8.58)

#775 for ETX-125EC: **149.95** (13.38)

#932 45° Erecting Prism for ETX®

For terrestrial observing with any ETX-90 or ETX-125 model. Yields correctly oriented image and convenient 45° observing angle. Threads to ETX rear cell. Accepts any 1.25" eyepieces. Coated roof prism optics. **$49.95** (3.86)

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#887: Yields *rock-solid* stability for sensitive applications of the ETX-125, even at high magnifications. **Includes fixed-height tripod convenient for standing observations, equatorial wedge with alignment controls in azimuth and latitude angle, and #889 Tripod Adapter for ETX-125.** Permits either altazimuth or equatorial orientation of the telescope for astronomical or terrestrial observing. Tripod legs are 2"-diameter chromed steel. For field use the tripod collapses for easy transport. **$349.95** (14.00)

Tripod Adapter for ETX-125

Included with the #887 Tripod *(above)*, the #889 Adapter is available separately and permits attachment of ETX-125 directly to any Meade LX10, LX50, or LX200 Schmidt-Cassegrain Field Tripod for altazimuth observing or to any Meade Schmidt-Cassegrain Tripod-with-Equatorial Wedge or Superwedge for equatorial applications.

#889 Adapter: **$69.95** (7.70)

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#883: Custom-designed by Meade specifically for ETX-90 and ETX-125 Astro Telescopes. Tripod height adjusts from 34" to 54", for seated or standing observations. Micrometric controls in azimuth and elevation permit precise polar alignment of the ETX fork mount. Tripod head tilts and locks to 90° for terrestrial applications. Telescope attaches to tripod in seconds with 2 thumbscrews. All-aluminum construction. **$199.95** (10.00)

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#1244 Electric Focuser for all ETX-90 models: **$119.95** (6.85)

#1247 Electric Focuser for ETX-125 models: **$119.95** (6.85)

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Readers Responded

Greetings from Berekum Secondary School and Ghana. I am a Peace Corps volunteer and have been teaching here since August 1998. Last July, I wrote to "Talking Back" asking for advice on how to locate astronomy resources to incorporate into my teaching curriculum. I have received more than 60 responses to that plea.

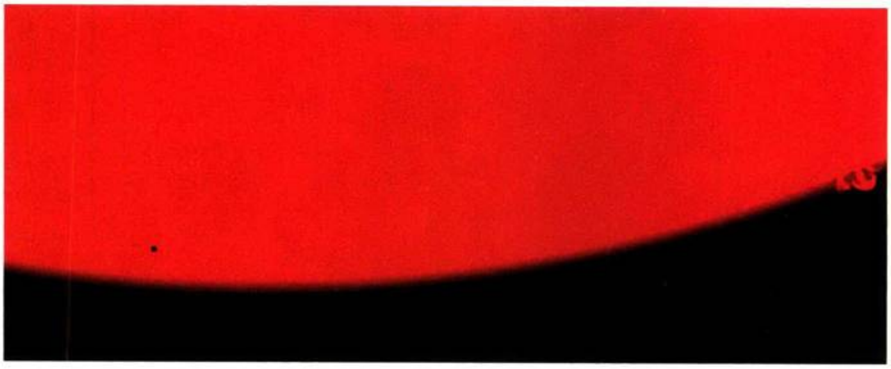
One respondent, Dan Brodt of Pasadena, Maryland, provided my school with a five-year collection of *Astronomy* magazines. This is an invaluable contribution to our newly established astronomy library.

On behalf of the staff and students at Berekum Secondary School, I would like to thank you for your interest and support. Your efforts are very much appreciated. — *Erika J. Cooley, Berekum, Brong-Ahafo, Ghana, West Africa*

In Transit

Something is not right with a Mercury transit photograph that appeared in your February 2000 issue. On page 118, the distance between Mercury and the limb of the sun is more than three times Mercury's apparent diameter of 9.94". In actuality, the separation between Mercury's limb and the sun's limb never exceeded 6.36" as seen from anywhere on Earth. Based on the apparent diameter of the sun in the photograph, Mercury's approximate position may be correct, but its diameter is only about 40 percent of what it should theoretically be. Printing processes may have altered the appearance of this event, which is shown more accurately on page 115 of the same issue. — *John E. Westfall, Coordinator, Mercury/Venus Transit Section, Association of Lunar and Planetary Observers, San Francisco, California*

The image in question is not a photograph, but a drawing made from sketches at the eyepiece, so I'm not surprised that it doesn't withstand astrometric scrutiny by an expert. That said, however, the distance from the limb to the center of the planet is significantly greater in hydrogen-alpha light than in white light because at the hydrogen-alpha wavelength the apparent solar limb is defined not by the top of the photosphere but by the top of the chromosphere. If you desire further clarification, please check out my website: http://www.davidcortner.com/astro/transit/. — David Cortner, Lenoir, North Carolina



David Cortner used a hydrogen-alpha filter to image Mercury transiting the sun.

Global Astronomy

As a non-U.S. reader, the only thing I find missing from *Astronomy* is geographical balance. For example, in the last 20 years, Spain has gone from contributing virtually nil to astronomy and astrophysics to currently being the site of three leading observatories: Spain's Mount Teide, Calar Alto, a Spanish-German endeavor, and La Palma Island, an all-European observatory. Additionally, we have two astrophysical institutes, Andalusia and Canaries, as well as several university departments active in the field. Spain is part of the European Space Agency and aims to have a small space program of its own.

Despite all this, I never seem to find news from Spanish astronomy (Indeed, I seldom find non-U.S. astronomy at all.) in *Astronomy*. Could you please include more information on astronomical news from Europe, Russia, Japan, Latin America, and elsewhere? While I understand that most of your readers are from the United States, I can think of an undertaking no more universal than astronomy. And I'm sure American readers would like to know what is happening in astronomy in other parts of the world. — *Rafael Moro Aguilar, Madrid, Spain*

A point well taken: The latest statistical analysis of Astronomy*'s readership shows that just over 17 percent of our readers are from outside the United States. — Astronomy* editors

Shoemaker and the Bard

Thank you for the February 2000 article on Gene Shoemaker by Carolyn Porco. How fitting that Gene's ashes were aboard the lunar prospector when it plunged into the south polar region of the moon on July 31, 1999 — thus leaving his own little crater on the moon. Equally fitting was the quote from Shakespeare's *Romeo and Juliet* on a plaque that accompanied his ashes. It reminds me of a quote from *Macbeth*: "Nothing in his life became him like the leaving it. . . ." — *Mike Orlins, Chattanooga, Tennessee*

Hunting Better Statistics

The work of Marcy and Butler and others discussed in "Hunting Planets Beyond" (March 2000) holds a place in

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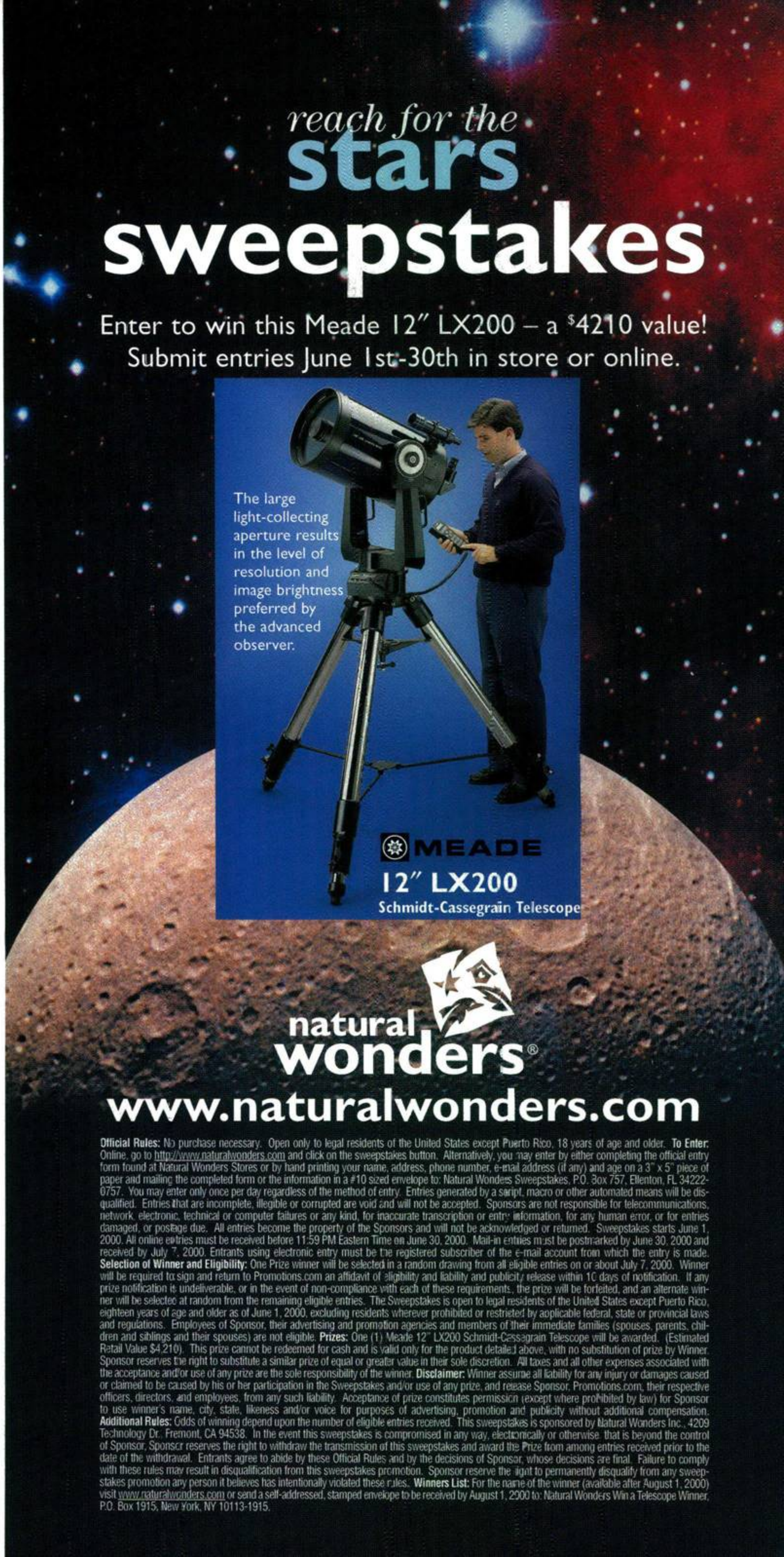

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the archives of astronomical history. But I am surprised at the conclusions of these researchers regarding the distribution and types of planets in the galaxy. By definition, they found only Jupiter-plus-size planets at mostly close-in orbits. Their sample size is much too small. To conclude anything about the distribution and characteristics of planetary systems from that is like drawing conclusions about cholesterol levels in the human population when all you can measure is levels above 200, in a sample of 33. — *Robert Powell, Austin, Texas*

Make a Date

While reading the many articles over the past few months concerning our missions to Mars and elsewhere, I often see references to starting missions on the day of some historic NASA event. What is the point of flying the Kitty Hawk mission on Mars during the 100th anniversary of the original flight? Why land humans on Mars 50 years after landing on the moon? Apollo 11 was one of the most amazing accomplishments in space history. Instead of hiding in its shadow, let's make our own historic day. When we land humans on Mars, do it on a day that has no significance of anything. Make it a new day to remember. — *Brian M. Hoxie, Seattle, Washington*

Is enough enough?

We thoroughly enjoyed "Mars Exploration: The Sounds of Silence" (AstroNews, March 2000), especially its optimistic diagram. It strikes us as strange that future expeditions would "pave the way for human exploration" so soon; having hit its tiny target at such a great distance really seems enough for now. — *Rev. Philip Sater, Elmira, New York*

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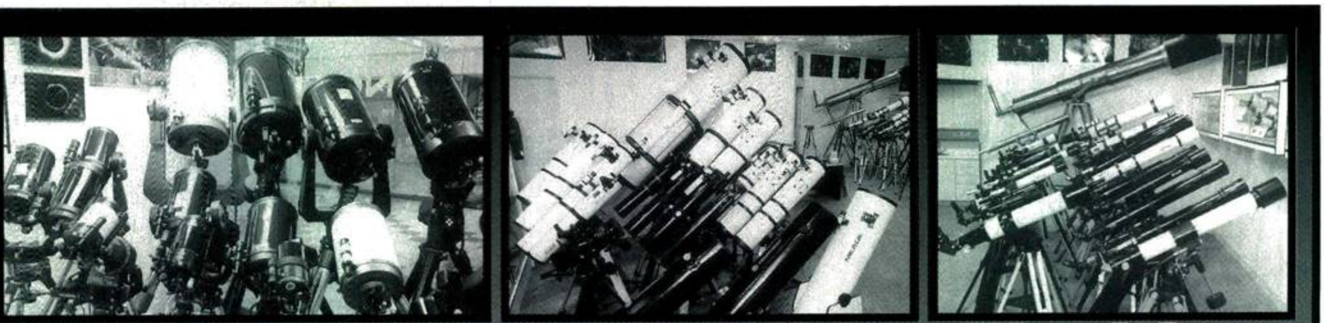

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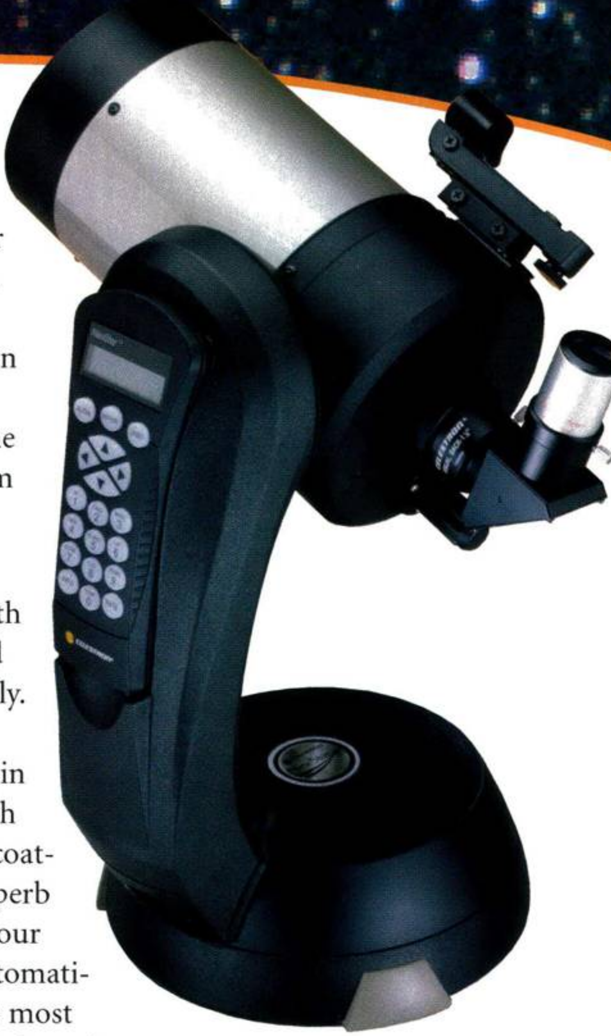

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OPTICS – all **HD** series telescopes have diffraction limited, premium optics manufactured to Celestron's uncompromising standards. The star images are classic textbook Airy disks. The Newtonians have multicoated optics and the refractors are fully multicoated to provide higher light transmission yielding bright, high contrast images.

The refractors have very good color correction. The 150mm Newtonian uses a state-of-the-art proprietary optical design incorporating an auxiliary correcting lens to reduce various aberrations, flatten the field and allow the tube length to be shortened – and it is superior to most fast parabolas.

MOUNT AND TRIPOD – the **HD** telescopes use the CG-4 German equatorial mount. It is a precision, heavy-duty mount which is upgraded and much better than the older polaris mounts.

The precision worm gears are extremely smooth in motion and the tracking accuracy is excellent. Optional motor drives make astrophotography easy and fun.

The tripod is a sturdy, adjustable height unit made of aluminium and it includes a heavy-duty accessory tray.

In addition, the 102mm refractor is offered with a **HD** altazimuth mount. This mount is easy to use and has slow motion controls (flexible cables) on both axes to allow for quick and easy pointing and tracking.

The superb optics with rigid mount and tripod of the **HD** telescopes allow you to enjoy awesome details of our moon such as craters, rills and mountain ranges; Saturn and its rings; Jupiter with its belts and moons; Mars, Venus and Mercury; deep-sky objects such as galaxies, nebulae, double stars and star clusters.

C150-HD
C102-AZ
C80-HD

For more detailed information on these telescopes, contact a Celestron dealer or Celestron.
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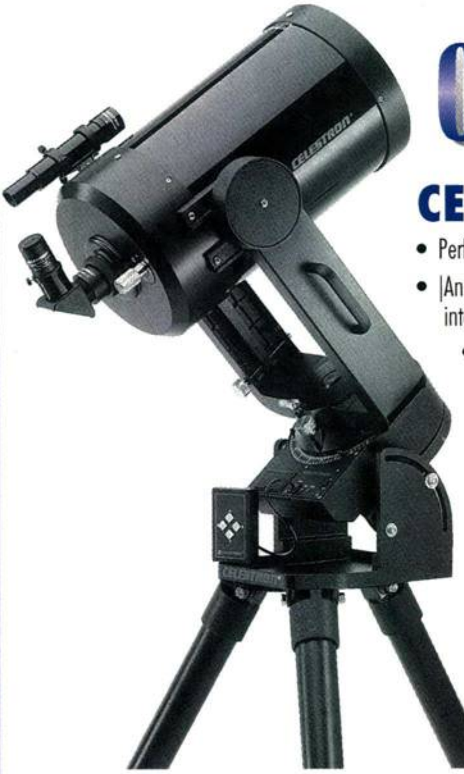
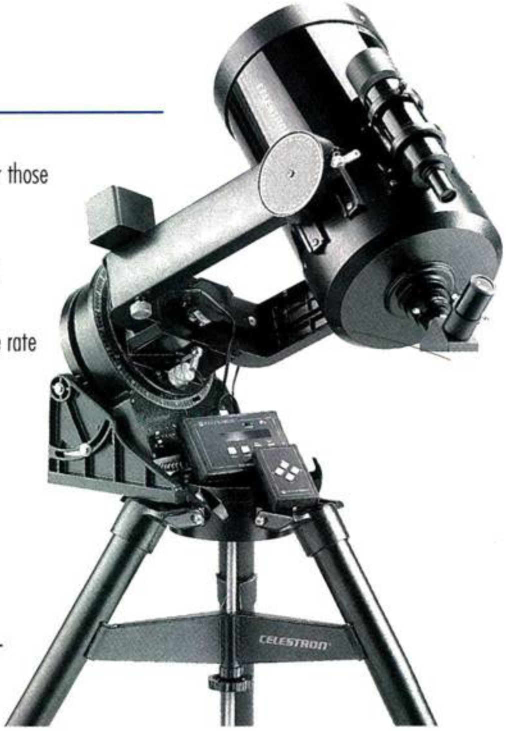


CELESTAR 8 TELESCOPES

CELESTAR 8

- Perfect for a first time astronomer.
- |An economical but full featured 8" (2032mm f/10) Schmidt-Cassegrain. A considerable amount of engineering work went into the design of the Celestar 8.
- No sacrifice was made in the optics. Celestron's carefully hand-figured system delivers diffraction-limited optics of unsurpassed quality. Starbright® coatings are standard.
- The energy efficient DC electronics are powered by a 9 volt alkaline battery for easy astronomy on the go.
- The totally cordless electronics have a built-in drive corrector which is activated when using the optional hand control. The R.A. motor's main tracking speed is an accurately regulated sidereal rate. The optional hand control allows for fast and slow override of R.A. tracking speed and ± operation of the optional DEC motor. A comment from the Sky & Telescope review – "the digital electronics delivered a near-perfect sidereal tracking rate."
- The Celestar 8 drive can operate in the Northern or Southern hemisphere from 0° to 90°.
- The unique Wedgpod is a combination tripod and wedge which is very stable.
- Made in the U.S.A.
- Standard accessories include: 6x30 Finderscope, Star Diagonal – 1¼" and a 25mm SMA Eyepiece – 1¼" (81x).
- Weight – 41 pounds.



CELESTAR 8 DELUXE

- For the more serious astronomer.
- This telescope utilizes the same superior optics and has all the features of the Celestar 8, but is enhanced, for those who prefer a premium version.
- This model has a heavier duty fork mount and drive base, with a precision worm gear drive system.
- Superior tracking accuracy is attained with this advanced drive system, which has four tracking rates and PEC (Periodic Error Correction).
- For the kind of versatility that makes observing a pleasure, the hand controller makes available a micro guide rate of .5x sidereal and a slew rate of 8x sidereal.
- The stepper motor drive electronics are cordless and operate on two 9 volt batteries.
- The Celestar 8 Deluxe has many features that are necessary for the more serious amateur astronomer, particularly if you're interested in astrophotography or CCD imaging with the PixCel or other CCD cameras.
- Fastar compatible for f/1.95 CCD imaging – deep sky images in 30 seconds or less!
- Made in the U.S.A.
- The standard accessories for this telescope include: Declination Motor, Car Battery Adapter, Hand Controller, Wedge and a Tripod with adjustable height that's exceptionally rigid and sturdy .
- Also standard is a large 9x50 Finderscope, Star Diagonal – 1¼" and a multi-coated 26mm Plossl Eyepiece – 1¼" (78X).
- Weight – 52 pounds.

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Contains an RS-232 serial interface to enable usage with programs like "The Sky"™ by Software Bisque.

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ACCESSORIES BY CELESTRON

The Celestron Accessories here are universal – use with virtually any telescope.

PLÖSSL EYEPIECES

In a recent *Sky and Telescope* review, Celestron's 1¼" Plössl eyepieces were rated as **top ranking**, and found to outperform many similar, but more expensive eyepieces. An exceptional value! Celestron offers these premium eyepieces at affordable prices, yet they're among the best designed and corrected eyepieces available. They're **multicoated** for enhanced contrast and all models are threaded to accept Celestron colored eyepiece filters. **Focal length with field of view:** 6.3mm (52°), 7.5mm (52°), 10mm (52°), 12.5mm (52°), 17mm (52°), 20mm (52°), 26mm (50°), 32mm (52°), 40mm (46°).

ULTIMA® EYEPIECES

These are Celestron's top of the line 1¼" eyepieces. They feature long eye relief and a wide field, and each air-to-glass surface is **fully multicoated** to enhance contrast levels. These special eyepieces are computer designed to keep visual aberrations to an absolute minimum. Recently, *Sky and Telescope* reviewed Celestron's Ultima® eyepieces and rated them **best in their class**, with greater contrast and image sharpness than the competitive models of other manufacturers. The inside surfaces and edges of all lenses are blackened, to keep out reflected light. Threaded barrels accept Celestron thread-in filters. **Focal length with field of view:** 5mm (50°), 7.5mm (51°), 12.5mm (51°), 18mm (51°), 24mm (51°), 30mm (50°), 35mm (49°), 42mm (36°).

LV EYEPIECES

These Vixen brand 1¼" eyepieces (6 to 8 elements) are a new breed, using the rare earth glass lanthanum in one of their field lenses, for almost total freedom from any visual aberrations. All focal lengths have a comfortable 20mm of eye relief. Even when using the 2.5mm LV eyepiece on a telescope, you'll have eye relief of 20mm! These eyepieces also feature **fully multicoated** lenses for optical excellence. **Focal Length with field of view;** 2.5mm (45°), 4mm (45°), 5mm (45°), 6mm (45°), 9mm (50°), 10mm (50°), 12mm (50°), 15mm (50°), 20mm (50°), 25mm (50°).

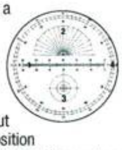
LV ZOOM EYEPIECE

This super premium 1¼" zoom eyepiece has a focal length of 8mm to 24mm. It is the finest zoom eyepiece for low to medium power observing. It's an excellent eyepiece that performs superbly, with **fully multicoated** surfaces. It offers an apparent field of 40° at 24mm and 60° at 8mm. Eye relief ranges from 15mm to 19mm.

CROSS HAIR EYEPIECE

This 1¼" eyepiece is of the Kellner design, with a focal length of 20mm. It's ideal for centering alignment stars when using digital setting circles or computerized telescopes. A useful all-around eyepiece for many applications, including terrestrial observing.

MICRO GUIDE EYEPIECE



This multifunction 1¼" guiding eyepiece features a laser-etched reticle with a built-in battery illuminator. The eyepiece is a **multicoated** 12.5mm Orthoscopic. Usage possibilities include: direct guiding on stars outside the center of the field of view; greatly improved off-axis guiding to capture much fainter, sharply focused guide stars without reducing limiting magnitude; and measuring position angles and separation of double stars. **Its finely etched micrometer scale** has gradations 50 microns apart and 15 microns wide. Included are: the eyepiece, built-in cordless illuminator with adjustable brightness control, batteries and instructions.

BARLOW LENSES

Celestron's premium quality .96" and 1¼" achromatic Barlow lenses are compact and lightweight. Both are under three inches long, with the 1¼" lens weighing in at 4 ounces and the .96" lens a mere 2 ounces! The clear aperture is 27mm on the 1¼" model, and 21mm on the .96" unit. The .96" Barlow is **fully multicoated** and the 1¼" lens is **multicoated**. The Ultima® Series Barlow (2x – 1¼") is an air-spaced, three element apochromatic design with a 27mm clear aperture. This lens features a very high quality, **fully multicoated** design. Amazingly compact and lightweight, it's just 5 ounces and 2¾" in length.

DIAGONALS

Celestron's Erect Image Diagonals are an Amici prism design. This design allows you to look into the telescope at a 45° angle, at images that are oriented properly, meaning the image is upright and correct from left to right. .96" to 1¼" models are available. Use of Celestron's hybrid .96" to 1¼" 45° Erect Image Diagonal on a telescope equipped with .96" eyepieces means greater versatility. This diagonal will allow you to use 1¼" eyepieces to obtain a larger field of view and better eye relief. A 90° 1¼" Erect Image Diagonal is available for those who prefer that angle. A 1¼" Star Diagonal (90°) is also available.

EYEPIECE FILTERS

Eyepiece filters are an invaluable aid in lunar and planetary observing. They reduce glare and light scattering, increase contrast through selective filtration, increase definition and resolution, reduce irradiation and lessen eye fatigue. Celestron's filters are made of high quality, solid plane parallel glass with excellent homogeneity. They're **antireflection coated** to prevent glaring and ghosting. All eyepiece filters are threaded to fit Celestron's, and most other manufacturer's, 1¼" eyepieces, and offer a full 26mm clear aperture. Filters available individually are: #12 Deep Yellow, #21 Orange, #25 Red, #58 Green, #80A Light Blue, #96 – 25% T, #96 – 13% T, Polarizing. In addition four different sets of four filters each are available.

1¼" POLARIZING FILTER SET

It's particularly useful for reducing glare while observing the moon, double stars, the planets and terrestrial subjects. You can vary the degree of transmission. By causing the amount of transmitted light to vary, the filters become, in effect, a continuously variable neutral density filter.

LPR FILTERS

Light Pollution Reduction (LPR) Filters are designed to selectively reduce the transmission of certain wavelengths of light, specifically those produced by artificial light. As a result, Celestron LPR Filters darken the background sky, making deep-sky observation of nebulae, star clusters and galaxies possible from urban areas. While blocking unwanted light, Celestron LPR Filters permit the transmission of more desirable wavelengths. This will improve your viewing of emission nebulae, both from urban and rural settings. They're also protected with a **broadband antireflection coating** to prevent ghosting and to improve contrast. They provide superior performance and contrast over competitive models. A 1¼" model threads into 1¼" eyepieces to work with virtually all telescopes.

MOON FILTERS

Celestron's Moon Filter threads into 1¼" eyepieces and aids in reducing the brightness of the moon and improving contrast, so greater detail can be observed on the lunar surface. The clear aperture is 21mm.

VIBRATION SUPPRESSION PADS

Telescope vibration is caused by windy conditions, an unsteady mount or tripod or even an accidental bump to the instrument, and results in reduced image quality. Celestron's set of three Vibration Suppression Pads **will reduce vibration time by almost 100%** and decrease vibration amplitude. The pads fit between the bottom of the tripod legs and the ground, a simple and functional solution to the problem of image disturbance.

NIGHT VISION FLASHLIGHT

Celestron's premium model for astronomy uses **two red LEDs** to preserve night vision better than red filters or other devices. Brightness is adjustable. Operates on a single 9 volt battery (included).

LENSPEN™

A superb new tool in optical lens cleaning technology. Perfect for cleaning binocular lenses, small aperture spotting scopes and telescopes, eyepieces, and other optical items. The LensPen™ comes with a handy retractable dust removal brush and a special non-liquid cleaning element, designed to never dry out. Safe and very easy to use.

SKY MAPS

Celestron Sky Maps are the ideal teaching guide for learning the night sky. You wouldn't set off on a road trip without a road map, and you don't need to try to navigate the night sky without a map either. Even if you already know your way around the major constellations, these maps can help you locate all kinds of fascinating objects. The front cover has a specially designed **luminous planisphere** that rotates to simulate the seasonal progression of celestial objects through the sky. When the planisphere is pre-exposed to light, star positions glow brightly against a dark background, mimicking actual constellations. More than a thousand stars and deep-sky objects are listed and charted.

PLANISPHERE

A simple and inexpensive tool for all levels of observers, from naked eye viewers to users of highly sophisticated telescopes. The Celestron Planisphere makes it easy to locate stars for observing and is a great planet finder as well. The Celestron Planisphere comes in three different models, to match the latitude from which you're observing: 20° to 40,° 30° to 50,° 40° to 60°.

TELESCOPE EQUATORIAL MOUNT–CG-3

A durable, rigid, German equatorial mount with a wooden tripod, offering both affordability and high quality. Designed as an excellent and inexpensive upgrade option when you're ready to move to a sturdier mount for your beginning telescope. R.A. and DEC setting circles, a latitude scale, slow motion controls and a handy accessory tray are included.

TELESCOPE EQUATORIAL MOUNT–CG-4

The CG-4 mount is a very rigid German equatorial mount. A counterweight, latitude scale, setting circles and slow motion controls on both axes are standard. The adjustable height aluminum, rigid tripod has **excellent damping characteristics** and a handy accessory tray. It is the same mount as used on Celestron HD telescopes and is a step up from the CG-3. Optional motor drives and a polar alignment finderscope are available.

TELESCOPE EQUATORIAL MOUNT–CG-5

The CG-5 EQ mount is the newest generation of Celestron's German mounts. Both axes of the equatorial mount have **precision worm gears** for extremely smooth motion. It is a step up from the CG-4. This **heavy-duty mount** delivers jitter-free images easily and the adjustable height aluminum, rigid tripod has excellent damping characteristics and a convenient accessory tray. Included are setting circles on both axes, slow-motion controls and latitude scale. An adjustable counterweight makes it easy to point, balance and use. An optional polar alignment scope for fast polar alignment as well as motor drives are available for easy tracking.

ALT-AZ PHOTO TRIPOD MOUNT

This heavy-duty mount is perfect for cameras with large telephoto lenses, and for spotting scopes and binoculars. If you already own a small telescope mount and are interested in one offering greater stability, the Alt-Az is an ideal upgrade. The adjustable wood tripod comes with two slow motion cables and is equipped with a ¼" x 20 photo head.

For more detailed information on these and other Celestron Accessories, contact a Celestron dealer or Celestron. Visit our Web site at www.celestron.com

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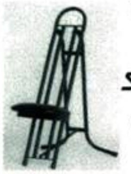

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Mention Ad A-7

EXTRASOLAR PLANETS

Breaking the Saturn Barrier

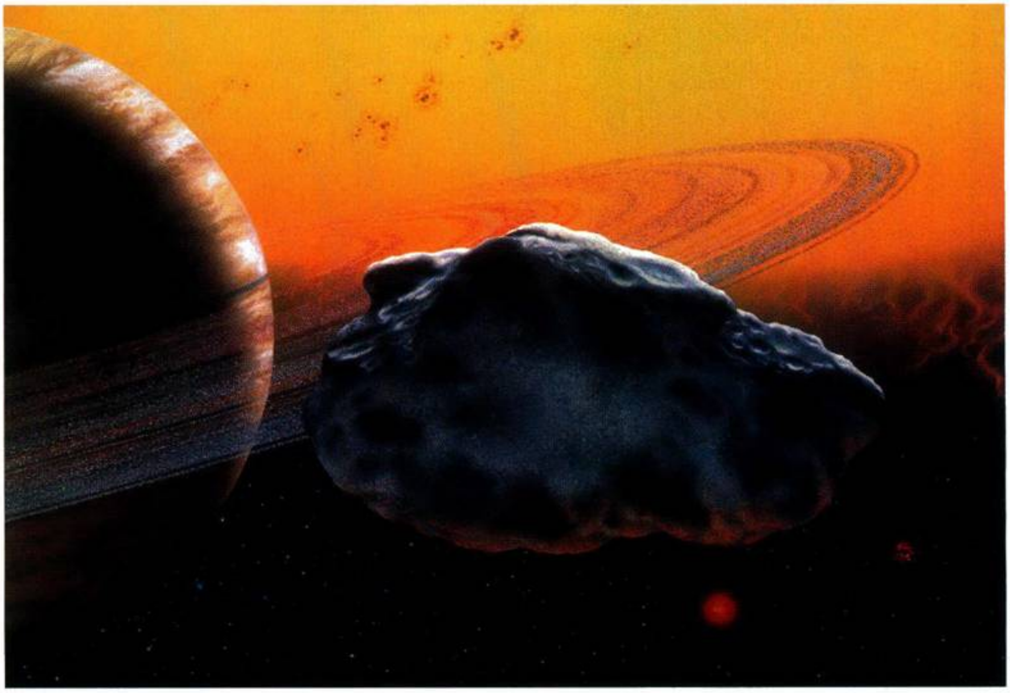
▶ Astronomers searching for planets outside the solar system have just crossed a critical threshold. They have found the first planets around sunlike stars that could be less massive than Saturn.

The planet-hunting team led by Geoff Marcy of the University of California at Berkeley and Paul Butler of the Carnegie Institution of Washington discovered both planets with the 10-meter Keck I Telescope in Hawaii. The planets orbit the solar-type stars HD 16141 and HD 46375. Each star lies about 110 light-years from Earth.

The HD 16141 planet has a minimum mass 72 percent the mass of Saturn (Saturn, in turn, is only 30 percent as massive as Jupiter). The planet orbits HD 16141 every 75 days in a highly elliptical orbit at an average distance of 0.35 astronomical unit (AU) — about the same distance that Mercury orbits the sun.

The planet orbiting HD 46375 could be termed a "hot Saturn." It tips the scales with a minimum mass 83 percent that of Saturn. Like seven other planets found to date, it orbits extremely close to its host star, at a distance of just 0.04 AU. It races around the star in a circular orbit every 3.02 days.

"It's very exciting to cross the Saturn threshold for the first time," says Marcy, whose team has discovered or codiscovered 25 extrasolar planets (see "Hunting Planets Beyond," March 2000). "These discoveries continue the trend of increasing numbers of planets having smaller masses. This points in the direction of Earth-size planets."



Lynette Cook

A new planet has been found orbiting the sunlike star HD 46375, one of two recently discovered planets with masses that could be less than Saturn's.

Besides these two sub-Saturn-mass planets, astronomers have recently announced five new extrasolar planets, raising the tally to 40. Marcy and Butler's team found three of the new ones. The others were discovered by teams led by Michel Mayor of the Geneva Observatory and Tim Brown of the National Center for Atmospheric Research. The five planets have minimum masses ranging between 1.1 and 7.4 Jupiters. Marcy admits that these five discoveries have generated little excitement. "It's nice to find Saturns," he says, "because Jupiters are getting to be old hat."

Marcy and Butler's team also has strong evidence that a second massive planet orbits the star Rho^1 Cancri, which is known to have a Jupiter-mass planet orbiting at 0.12 AU. "I'd bet my house on it," says Marcy, who says his team is waiting for the planet to complete its full 12- to 15-year orbit before officially announcing its existence.

Astronomers don't know exactly how massive these planets are because the technique they use to discover extrasolar planets is indirect and only enables a measurement of a planet's minimum mass. But it's unlikely the HD 16141 or HD 46375 planet has significantly more mass than Saturn. The technique can't detect Earth-mass planets, but Marcy says his team could soon find planets with masses as low as Uranus and Neptune (which are only about 5 percent as massive as Jupiter). — ROBERT NAEYE

SOLAR UPDATE

Seeing Moss and the Whole Sun

▶ Though a rolling stone gathers no moss, it appears that our churning sun does.

The Transition Region and Coronal Explorer (TRACE) satellite has found spongelike features that resemble earthbound moss

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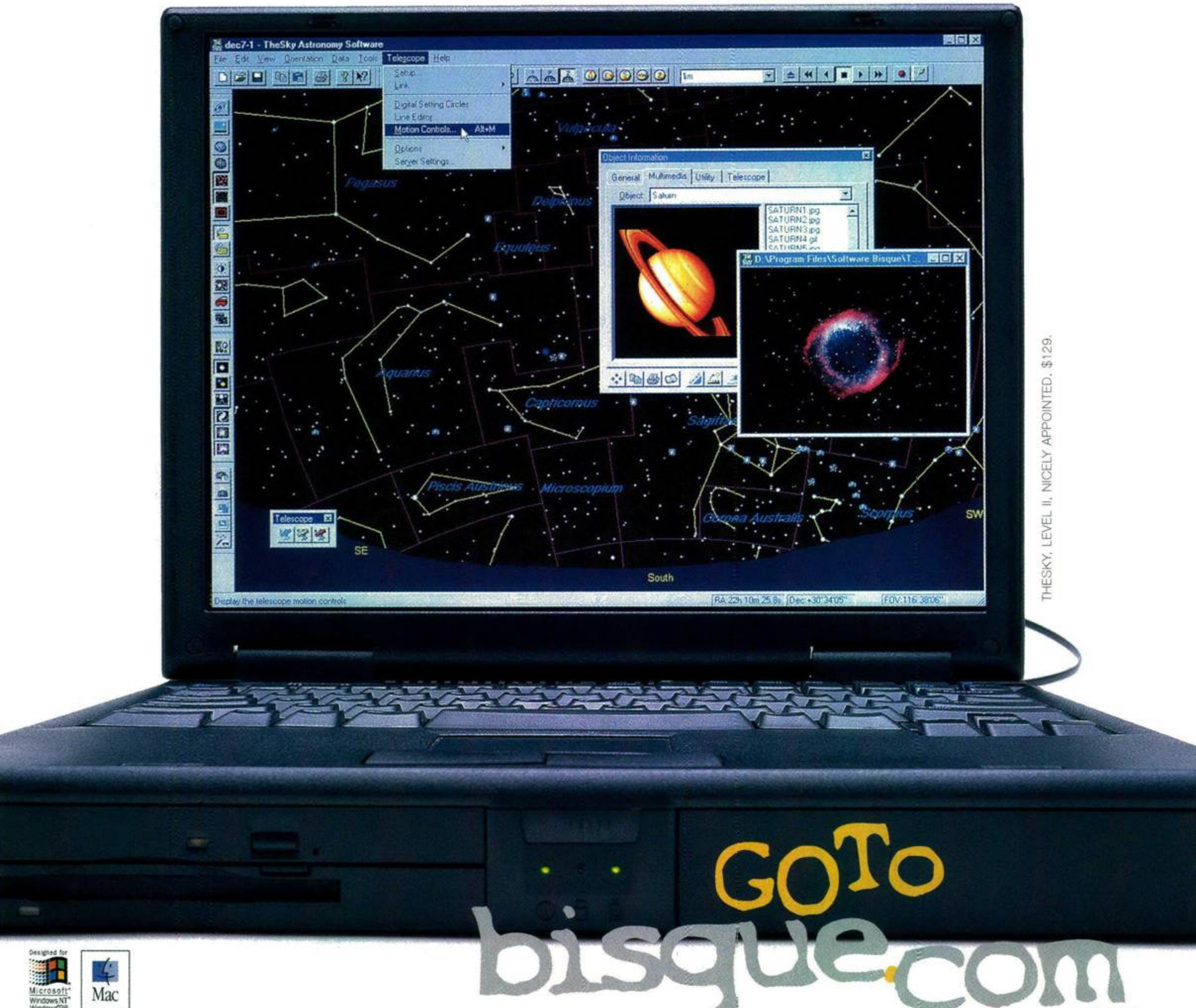
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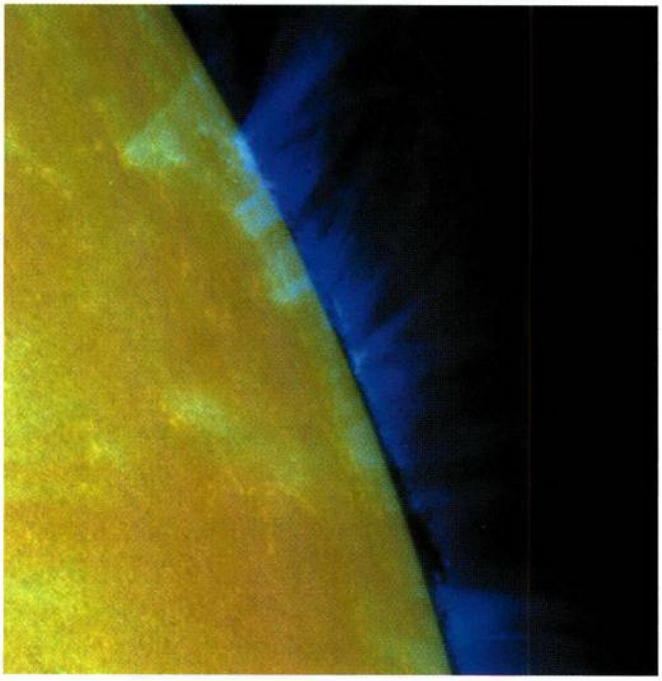


TRACE: NASA/Lockheed Martin/SAO/MSU

A layer of "moss" appears at the sun's limb in this composite image. The yellow image shows the sun's surface in visible light. The blue image comes from TRACE and reveals 1 million to 2 million degree coronal loops and a bright "layer" of moss just above the solar surface. The moss layer ranges between 1,000 and 2,500 miles above the surface.

plants. This "solar moss" may provide clues to the sharp temperature rise that occurs as you move from the sun's visible surface (photosphere) to its outer atmosphere (corona).

Solar moss appears only at the base of high-pressure coronal loops in extremely active regions of the sun. It forms in large, bright patches roughly 6,000 to 12,000 miles (10,000 to 20,000 km) across and from 1,000 to 2,500 miles (1,500 to 4,000 km) above the photosphere. The bright zones are hot gas or plasma that emits light in the extreme ultraviolet part of the spectrum. Interlaced with the plasma are dark voids caused by cooler gases jetted from the sun's lower atmosphere, the chromosphere. Together the hot plasma and cooler jets give these features their spongy, mosslike appearance.

"The TRACE observations show how the transition region between the sun's surface and its atmosphere is much more complex and dynamic than previously observed," says Bart De Pontieu of the Lockheed-Martin Solar and Astrophysics Lab. "These observations provide a glimpse of how the sun's magnetic field changes from a chaotic jumble at the photosphere to the well-organized magnetic field present in coronal loops."

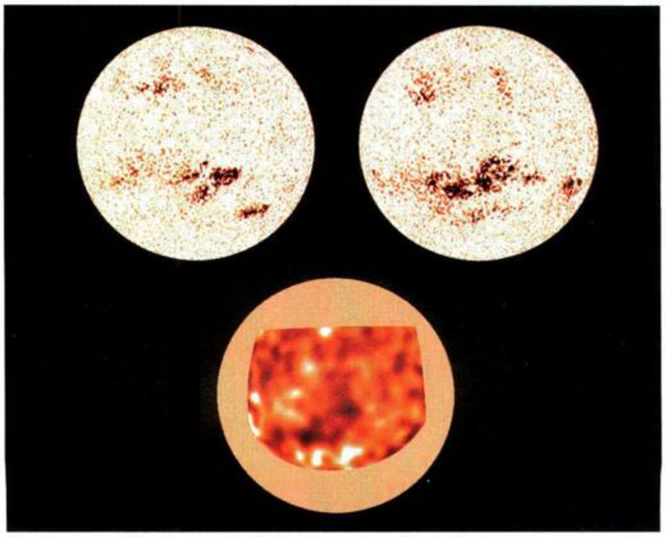
Highly active solar features such as coronal loops also affect space weather. Recently, the Solar and Heliospheric Observatory (SOHO) spacecraft tested a new technique that detects forthcoming solar storms on the sun's farside. It allows astronomers to predict the possibility of a dangerous solar outburst two weeks before an active region rotates into view.

The process uses sound similar to the way the eye uses light. The retina identifies subtle changes in light intensity and conveys those changes to the brain. SOHO's Michelson Doppler Imager (MDI), on the other hand, measures ripples at millions of points across the sun's visible surface. Computers then interpret these motions in terms of sound waves traveling through the sun's interior. Waves originating on the farside of the sun reach the nearside by rebounding internally. Those waves that originate or encounter the strong magnetic fields associated with active regions experience an increase in speed. As a result, these sound waves arrive at the sun's nearside about 6 seconds earlier than other waves.

"We've known for ten years that in theory we could make the sun transparent to the farside," says Charles Lindsey of the Solar Physics Research Corporation. "But we needed observations of exceptional quality. In the end we got them, from MDI on SOHO."

— Andrea Gianopoulos

The two upper images show the sun's magnetic-field strength measured with SOHO's Michelson Doppler Imager while an active region (dark area) was facing Earth — before (March 16, 1998) and after (April 12, 1998) being holographically imaged on the farside on March 29, seen in the lower image. SOHO/MDI team



X-RAY ASTRONOMY

Another Eye on the Universe

▶ "Up to now, everything has been working fine," says Fred Jansen, project scientist of XMM-Newton. This new x-ray observatory, launched by the European Space Agency (ESA) in December 1999, radioed its first images and spectra to Earth in January. To the great delight of x-ray astronomers, the images confirmed that all the instruments are working as planned.

Preliminary observations — so far used mainly to calibrate and commission the instruments — give a foretaste of what to expect.

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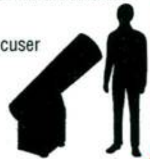

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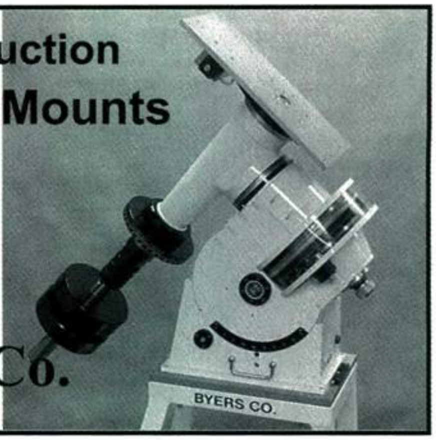

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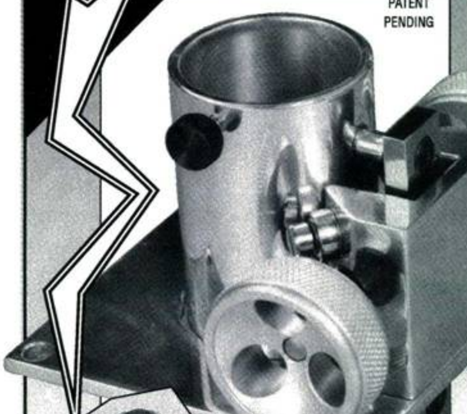

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"We already see spectral features in certain stars that had only been visible on the sun," says Bert Brinkman of the University of Utrecht in the Netherlands. And Richard Mushotzky, NASA's project scientist for XMM at the Goddard Space Flight Center in Greenbelt, Maryland, says the first scientific results are expected in the next few months. "We have very high expectations."

The 33-foot-long (10-meter) spacecraft carries a set of three x-ray telescopes, each made up of 58 concentric gold-plated, nickel-alloy mirrors that together have a total surface area of more than 1,300 square feet (120 square meters) — bigger than a tennis court. These mirrors focus the x rays on CCD cameras that record images of the observed objects but also measure the wavelength of the x rays.

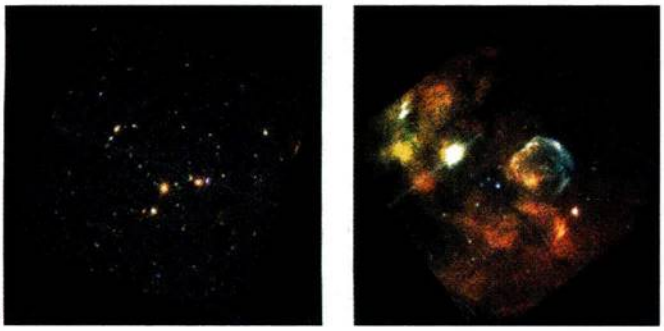
Two telescopes are connected to diffraction gratings that fan out the incoming x rays according to their wavelengths and produce spectra with a much higher precision than the CCDs. Compared with Chandra, the American x-ray observatory launched by NASA in July 1999, the imaging resolution of the telescopes is lower but the sensitivity is higher. That makes it suitable for observing x-ray sources that fluctuate quickly, says Robert Laine, ESA's project manager for XMM.

Just like Chandra, the XMM-Newton mission will study a host of objects that emit x rays: hot gas in galaxies, supernova remnants, jets produced by exploding stars and by black holes at the centers of galaxies, and the centers of active galaxies. The observations may also shed light on the enigmatic dark matter that apparently makes up about 90 percent of the universe's mass, says Brinkman, who is the principal investigator of the x-ray spectrometers aboard XMM. He hopes to observe Doppler shifts in the very hot gas found between galaxies and from that deduce their motion and the gravitational forces acting on them.

Unfortunately, a third x-ray observatory, ASTRO-E, failed to reach orbit when launched by Japan early this year. Because it would look at very high-energy x rays, which are beyond the reach of both Chandra and XMM, it would have completed the global x-ray view on the universe. "It's like a stool with three legs and you've lost one leg," says Mushotzky. "You can balance the stool, you can still sit on it, but it's a little wobbly."

— Alexander Hellemans

Left: ESA's XMM satellite took this x-ray image of Hickson Compact Group 16, a group of colliding galaxies 170 million light-years away. Right: The Tarantula Nebula in the Large Magellanic Cloud posed for XMM's first portrait. In these false-color x-ray images, blue represents the hottest temperatures, green intermediate, and red the coolest.



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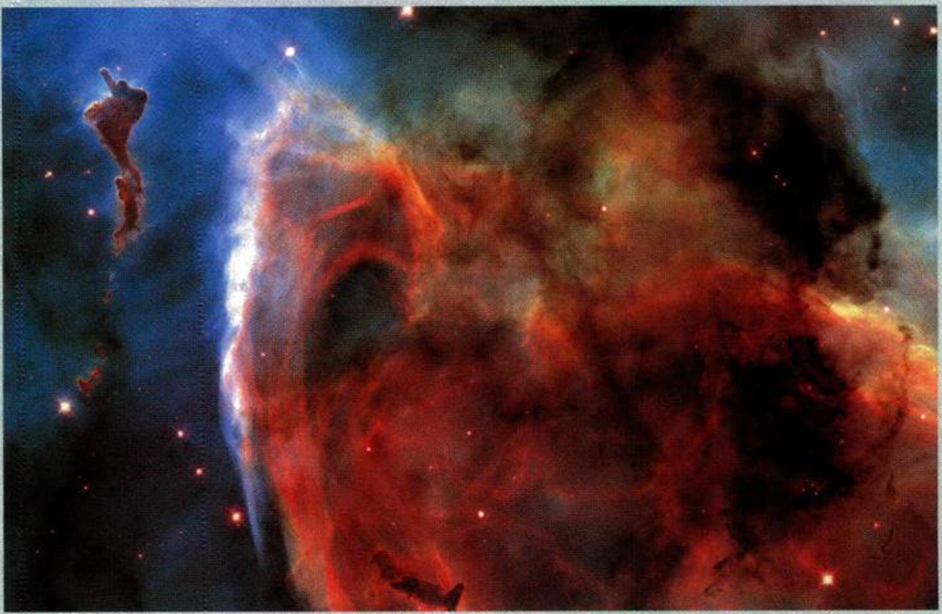

Hubble Heritage Team (NASA/STScI/AURA)

THE KEYHOLE NEBULA that surrounds the explosive variable star Eta Carinae takes center stage in this recent Hubble Heritage image. The large, approximately circular feature that dominates the image lies about 8,000 light-years from Earth in the southern constellation Carina. (Eta Carinae itself is just outside the field toward the upper right.) The nebula also contains several other stars that rank among the hottest and most massive known, each about 10 times as hot and 100 times as massive as the sun. The entire region plays host to numerous bright filaments of hot gas and dark clouds of cold molecules and dust, all of which are in rapid, chaotic motion. The Keyhole, named in the 19th century by Sir John Herschel, has a diameter of some 200 light-years, though the ring structure seen here spans only 7 light-years.

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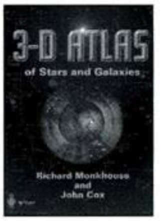

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A More Violent Solar System?

Take a look at the moon through binoculars or a small telescope and you'll be amazed at how many craters appear. From giant basins hundreds of miles across to depressions as small as the eye can see, craters seem to be everywhere.

The large majority of those craters formed more than 3.5 billion years ago, during the so-called heavy bombardment of the inner solar system. And to most people, that's where the story ends. Sure, there have been impacts in the eons since, but by and large the cratering rate dropped precipitously and remained low.

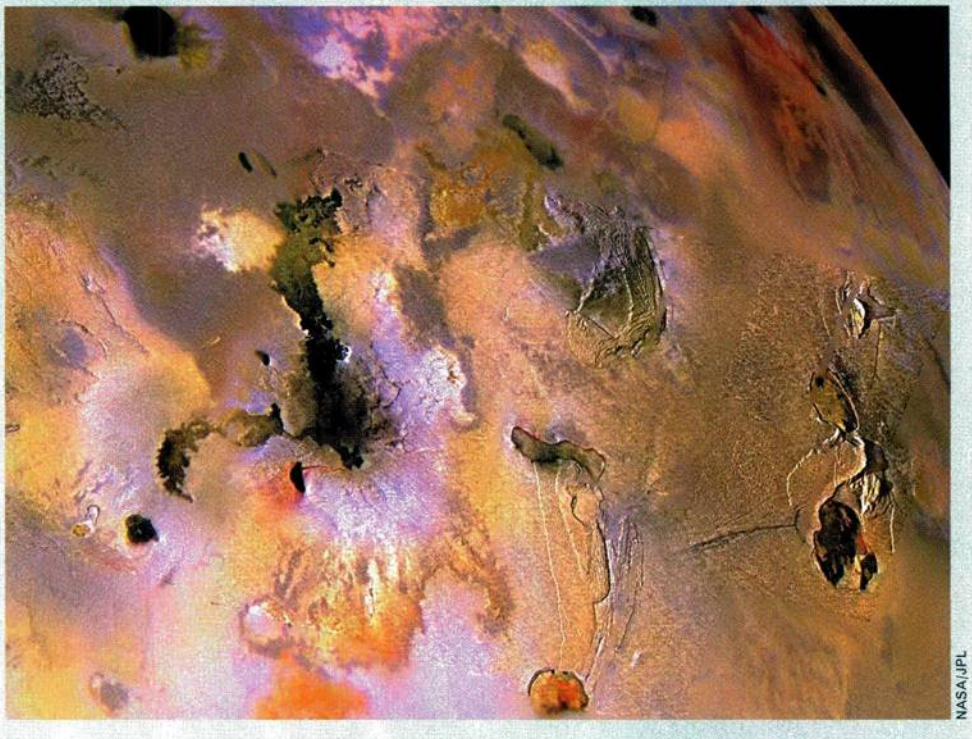
Yet that common wisdom now appears to be wrong. In the March 10, 2000, issue of *Science*, Timothy Culler of the University of California at Berkeley and his colleagues report that the rate of cratering dropped by a factor of two or three from 3.5 billion years ago to about 500 million years ago, but has *increased* by a factor of nearly four in the last 400 million years.

The researchers studied minute soil samples returned in 1971 by Apollo 14 astronauts. They found 155 tiny glass beads, most less than one-hundredth of an inch in diameter. Such spherules are created when a meteor strikes the surface and generates intense heat, which melts the rock and splatters it outward.

By analyzing how much of the radioactive potassium in the spherules had decayed into argon, they dated the samples and deduced the recent increase in bombardment of the moon and, by implication, Earth.

The study raises several intriguing questions yet to be answered. What caused the increase? Will this affect the dating of other planetary surfaces? And, perhaps most exciting — is it more than mere coincidence that complex life evolved on Earth at about the same time? — Richard Talcott

GALILEO



NASA/JPL

ERUPTING VOLCANOES and towering mountains punctuate the latest images of Io from the Galileo spacecraft. This view combines several high-resolution black-and-white images taken during the close flyby of October 10, 1999, with lower-resolution color images taken on July 3, 1999. This technique helps planetary scientists better understand the relationships between different surface materials and the underlying geologic structures. For instance, the red material appears to be a compound of sulfur and is often associated with lava erupting onto the surface. It can be seen best around the margin of Monan Patera, the elongated caldera to the lower right of center. The broad circle of bright white material just left of center probably represents sulfur dioxide deposited from the Amirani plume. The heights of mountains can be estimated by the lengths of the shadows they cast. The mountain near the mosaic's right edge is approximately 26,000 feet (8 km) high, and the one north of it rises about 13,000 feet (4 km) high. Surprisingly, Io's mountains do not appear to be volcanoes.

YOUNG STELLAR DISKS

A Clumpy Disk for Beta Pic

Since its discovery in 1983, astronomers have wondered why the dusty disk surrounding the young star Beta Pictoris is 20 percent longer and thinner on one side than the other. Dust disks around young stars, after all, are supposed to be more or less symmetrical.

Recently, a team led by Paul Kalas of the Space Telescope Science Institute in Baltimore, Maryland, may have found the telltale clue that will solve the mystery. Kalas's team scrutinized dozens of images of Beta Pic's disk taken with the Hubble Space Telescope and ground-based telescopes.

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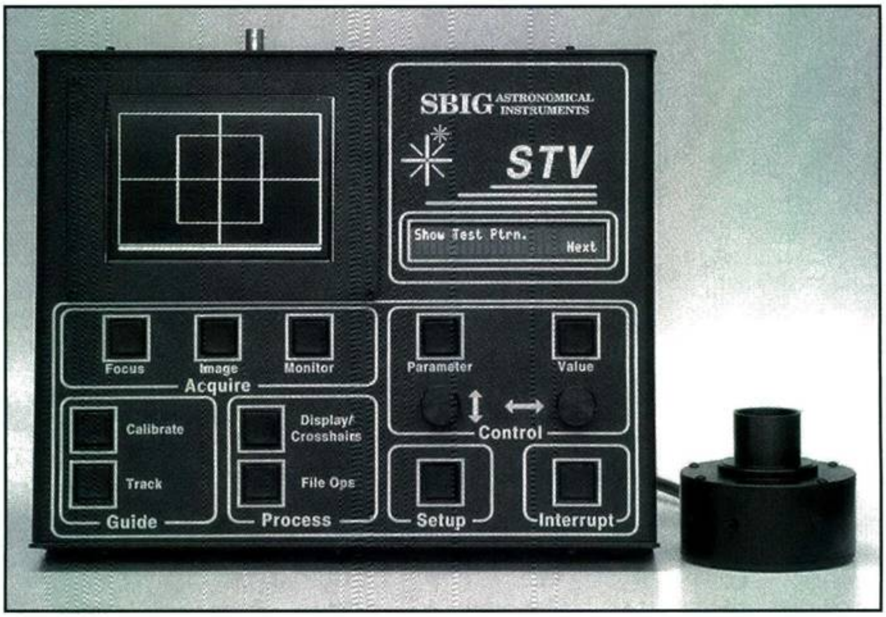
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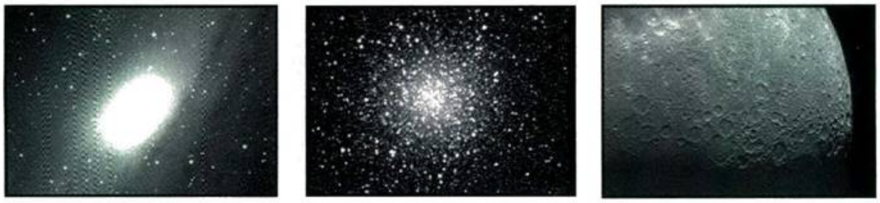

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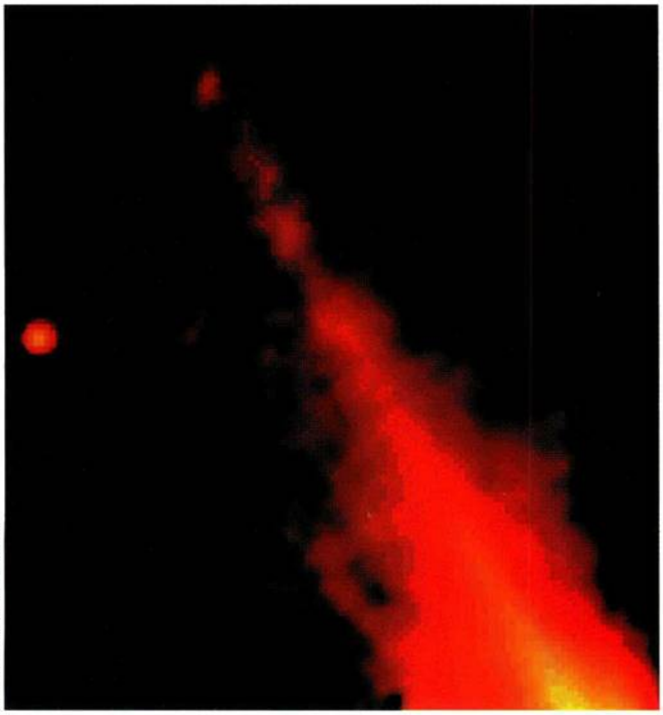


Paul Kalas (STScI) and NASA

Several dusty clumps lie at the outer edge of the disk surrounding Beta Pictoris. The clumps suggest that a star encountered the disk 100,000 years ago.

They noticed a previously overlooked feature: clumps of dust at the outer edge of the long, thin side of the disk. We view the disk from nearly edge-on, and the team suspects that the clumps would appear as rings if we could view the disk face-on. Because the clumps appear on only one side of the disk, the rings must be elliptical.

The group realized that a stellar interloper passing nearby could perturb the disk. To find out if this was possible, the team turned to theorist John Larwood of Queen Mary and Westfield College in London, England. Larwood's computer simulations show that a low-mass star passing within 700 astronomical units of Beta Pic 100,000 years ago can generate both the asymmetries and the rings.

Because stars are far apart, Kalas admits that the probability of such an encounter is only about 0.01 percent. But the universe is big enough for such rare events to occur, and the interloper model does a perfect job of explaining the observations. Kalas is currently searching for the interloper among several hundred stars near Beta Pic.

Astronomers are particularly interested in Beta Pic's disk because it is believed to be similar to the disk that surrounded the young sun and from which the planets and the more-distant Kuiper Belt of comets formed. If a passing star could perturb Beta Pic's disk, then certainly passing stars could have perturbed the young sun's disk or the Kuiper Belt. "The current appearance of Beta Pic may accurately represent an early stage of evolution for our solar system, when passing stars were disrupting the Kuiper Belt," says Kalas. — R. N.

New Name for NEAR

NASA's Near Earth Asteroid Rendezvous (NEAR) spacecraft, currently orbiting the asteroid Eros and returning images and other data, has been renamed NEAR Shoemaker to honor the legendary geologist Eugene M. Shoemaker. Shoemaker, who influenced decades of research on asteroids and comets, died in a 1997 car crash while studying impact craters in the Australian outback. He was a key member of the team that defined the NEAR mission's science objectives in 1985. "Gene Shoemaker was an inspirational and charismatic pioneer in the field of planetary science," said Carl Pilcher, Director of Solar System Exploration at NASA, in announcing the new name. "It is a fitting tribute that we place his name on the spacecraft whose mission will expand on all he taught us about asteroids, comets, and the origin of our solar system."

Johns Hopkins University and NASA

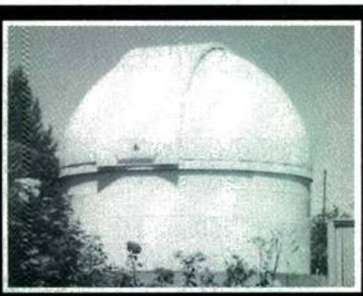
Eros's saddle stands out in this image from NEAR Shoemaker.

Record-setting Quasar Lies at the Edge

As the brilliant centers of active galaxies, quasars can be seen from a long ways away. Yet none had ever been seen from *this* distance. Daniel Stern of the Jet Propulsion Laboratory and his colleagues discovered a quasar that lies 13 billion light-years from Earth, making it the most distant object ever seen. The researchers used the 200-inch (5-meter) Hale Telescope at Palomar Observatory and the 157-inch (4-meter) Mayall Telescope at Kitt Peak to identify the candidate, then used the 10-meter Keck Telescope to analyze its light. "As soon as we saw the spectrum, we knew we had something special," says Stern. The quasar has a redshift of 5.5, meaning that the universe's expansion has shifted its light toward longer wavelengths by 550 percent. The cosmos was just 8 percent of its current age when light left the quasar.

SOHO Discovers Its 100th Comet

The Solar and Heliospheric Observatory (SOHO) is padding its lead as the world's leading comet hunter. SOHO made its 100th discovery on February 4, 2000. Nearly all of its finds have come with the LASCO instrument, which blocks out the sun's bright disk to watch for mass ejections that could disturb Earth's space environment. The comets are simply a bonus. Kazimieras Cernis of the Institute of Theoretical Physics and Astronomy in Vilnius, Lithuania, found number 100 by examining LASCO images on the Internet. Several other professionals and amateurs have discovered comets on SOHO images, which can be seen on the mission's website at http://sci.esa.int/soho/.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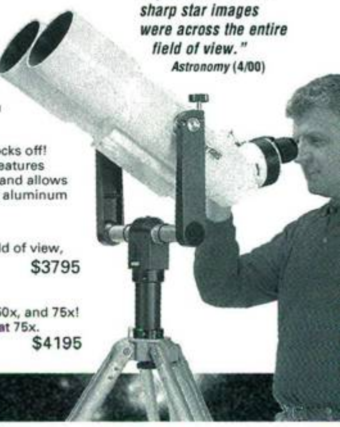

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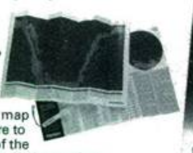

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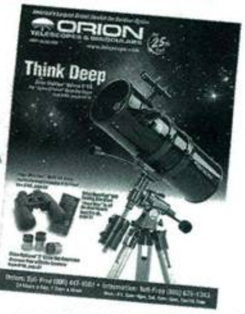

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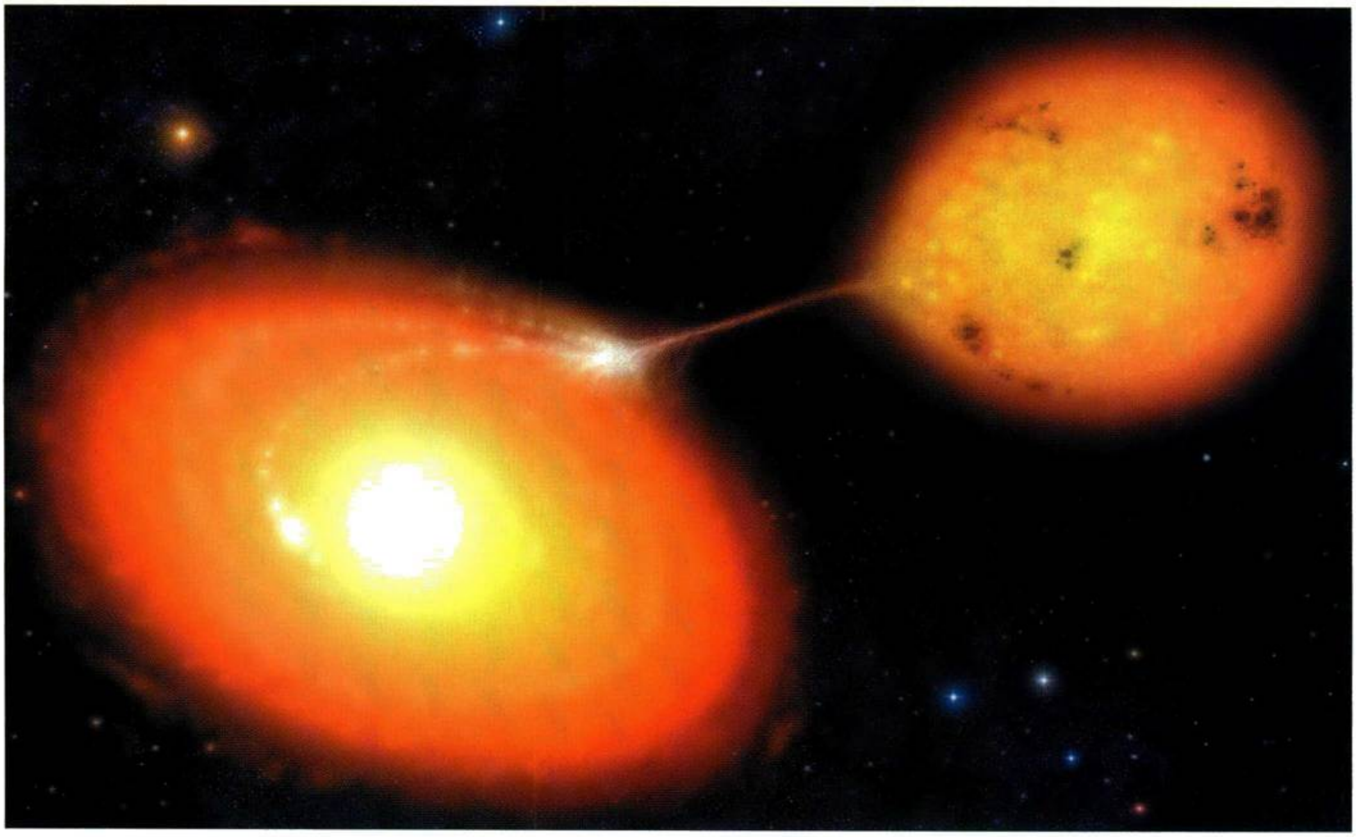
Text and illustrations by Mark A. Garlick

NATURE TENDS TO FAVOR COMPANIONSHIP WHEN IT comes to stars. The thousands of pinpricks shining in the night sky may look solitary to the unaided eye, but probably the majority of stars in our galaxy have one or more companions. These are real physical associations in which the members engage in a stately dance about their common center of mass. Sometimes, however, the dance turns frenetic.

Imagine a system where two stars orbit each other in just a few hours, so tightly that their separation barely amounts to a solar diameter. The larger of the two is a red dwarf: fairly normal, timid, not far from the main sequence where it calmly burns hydrogen into helium and spends most of its life. The smaller, however, is much less docile. It is a white dwarf — a stellar corpse with as much mass as our sun squeezed into a superdense sphere just a bit larger than Earth. Each pulls on the other with unyielding determination, but they play at a gravitational tug-of-war only one can win. The laws of physics leave the red dwarf no choice. It finally accedes to the gravitational demands of its cannibalistic partner, its tenuous atmosphere slipping away.

Plunging into the gravity well of the white dwarf, ten thousand million tons of gas every second surround the compact star in a glowing ring of plasma spanning half a solar radius. As the structure acquires more and more gas, it thickens and spreads, forming a luminous disk that reaches all the way to the photosphere of the white dwarf — where the gas begins to accumulate. But temperatures, pressures, and densities in this accreted gas eventually reach extremes, mimicking conditions at the center of a star. Months, years, or centuries, it is only a matter of time until the material erupts. A tremendous explosion rips through the accumulated gas, announcing its presence to anyone within hundreds of thousands of light-years: the shining beacon of a nova.

Novae — not to be confused with the far more powerful supernovae — have been seen exploding in our skies for centuries. Yet it was not until the last half-century that astronomers began to understand these objects. The standard picture of a nova arising when a white dwarf accumulates too much gas from a red dwarf was proposed in 1954. That was when Merle F. Walker of the Carnegie Institution of Washington discovered that the star designated DQ Herculis, which erupted as a nova in 1934, was an eclipsing binary system with an orbital period of just 4 hours and 39 minutes. It was the first time that the nova phenomenon had been linked to close binary stars, and it was exactly correct.



In a nonmagnetic cataclysmic variable (above), a white dwarf strips the atmosphere from a red dwarf, feeding an accretion disk. In an intermediate polar (right), the white dwarf's magnetic field prevents the disk from reaching the surface and channels gas from the "ring" onto the poles.

Since then, mass transfer between two stars has become old news. The violent outbursts that result have given rise to a more modern and all-encompassing name for this entire class of binary system: cataclysmic variables (CVs). To date, more than 800 CVs have been cataloged, and artists' impressions of them seem to appear everywhere. But these images fail to get across the fact that many CVs no longer conform to the standard picture. These systems display such diverse behavior that, over the last two decades, several subclasses have been introduced. Broadly speaking, astronomers now recognize five or six distinct subclasses — and two of these differ significantly, in appearance and activity, from the 46-year-old standard picture.

Magnetic Personalities

The key feature of these oddball subclasses is a strong magnetic field. Magnetic fields seemingly crop up everywhere in astronomy. Earth has a fairly weak field that averages about one-half gauss. The sun's overall field is just a few times stronger, though the fields in sunspots can run up to a few thousand gauss. Most solitary white dwarfs also harbor some degree of magnetism, which can reach millions of gauss. It's certainly not unreasonable to think that magnetic fields would exist in the white dwarfs found in cataclysmic variables as well.

Evidence that at least one CV might contain a magnetic white dwarf has been around since 1956. In that year Walker announced that the light output of DQ Herculis varied rapidly with a steady period of just 71 seconds. Theorists put forth several possible explanations, but none involved magnetic fields, and it took nearly two decades before people began to see these oscillations for what they really were.

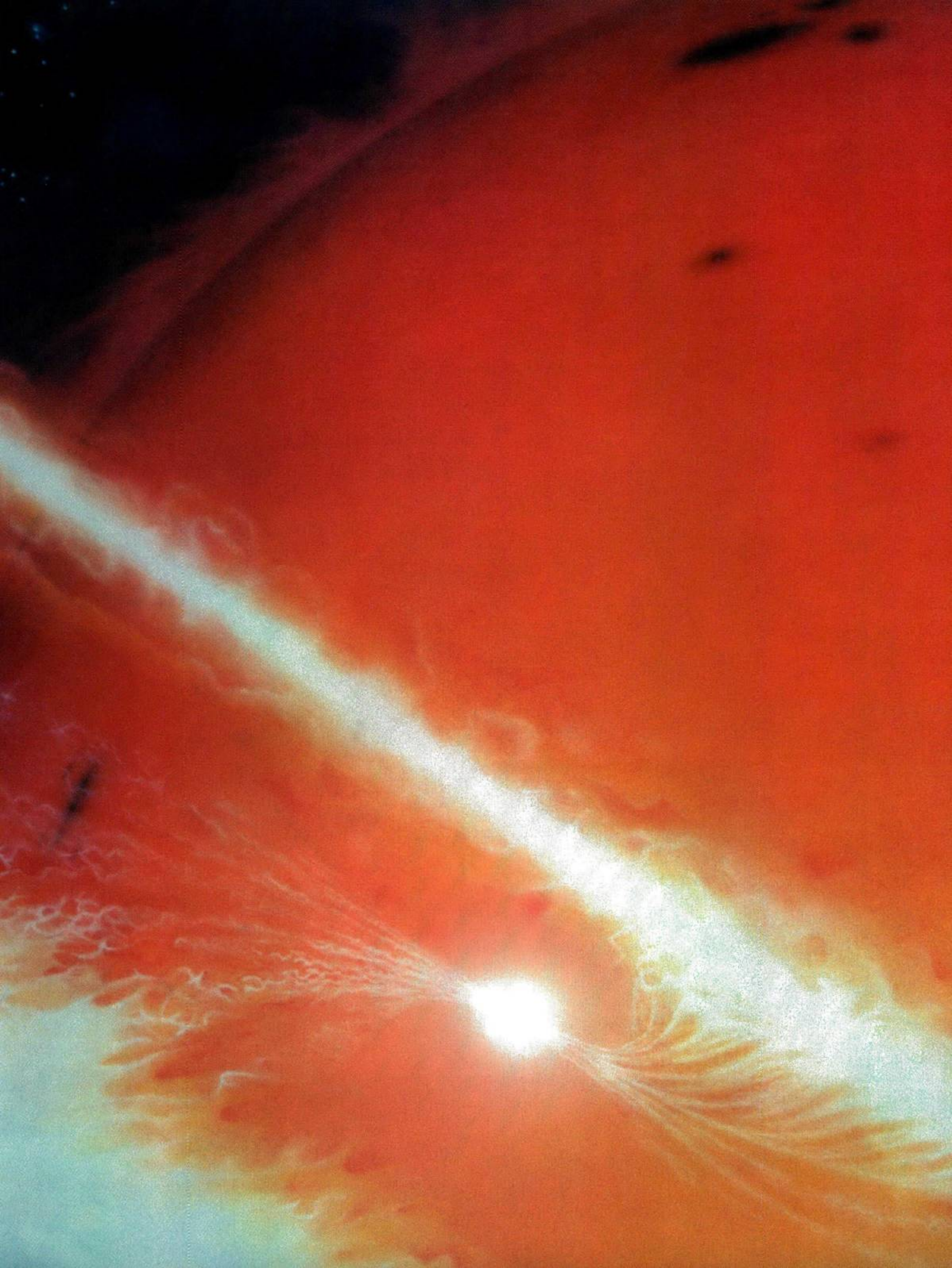
Finally, in 1974, scientists from Oxford and Brighton in the United Kingdom suggested that the pulsations might be coming from a highly magnetized white dwarf spinning on its axis once every 71 seconds. They proposed that the magnetic field was funneling material captured from the red dwarf onto the white dwarf's magnetic poles. (A similar process causes aurorae on Earth, as our planet's magnetic field channels protons and electrons from the sun into the polar regions.) When the material strikes the surface of the white dwarf, it generates an enormous amount of heat and light, creating localized hot spots on the white dwarf's photosphere. Then as the white dwarf rotates on its axis, the hot spots flash in and out of view and give rise to the pulsating signal that Walker discovered.

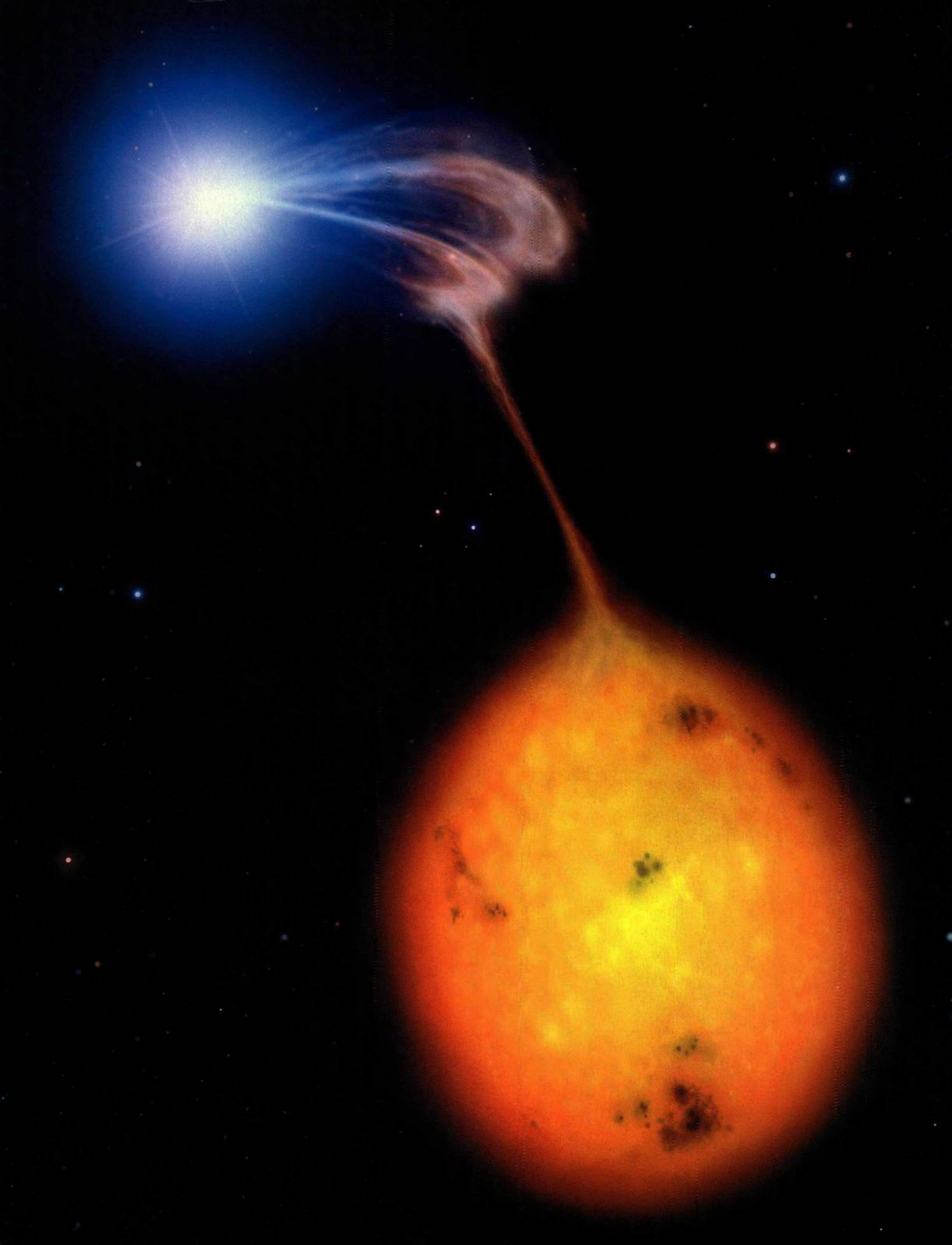
Independent observations also showed that the optical light from DQ Herculis is weakly polarized. Stars typically emit unpolarized light, meaning that the radiation contains a mixture of light waves whose electric fields are oriented in all possible directions. The discovery that the light from DQ Herculis showed a preferred orientation and that this polarization changed with the same 71-second period strongly indicated the presence of a magnetic field.

Astronomers quickly accepted this model, and magnetic cataclysmic variables were born.

An Exceptional Class

DQ Herculis was the first cataclysmic variable known to have a magnetic field, but since then at least 20 similar systems have been discovered. These objects form one of the CV subclasses and have been dubbed DQ Herculis stars, or intermediate polars (IPs) because they have a greater degree of





polarization than most cataclysmic variables but less than the most extreme class. IPs contain white dwarfs with magnetic fields up to a few million times stronger than Earth's. The orbital periods of the binary systems almost always measure a few hours. And the white dwarfs rotate with periods that range from tens of seconds to several thousand seconds — but always much shorter than the orbital periods. These attributes produce distinctive observational characteristics.

Because white dwarfs and their surrounding accretion disks are so hot, often with temperatures of tens of thousands or hundreds of thousands of degrees, CVs emit large amounts of high-energy radiation and typically appear brighter at x-ray or ultraviolet wavelengths than they do in the visible. All these emissions vary with the spin period of the white dwarf as well as the orbital period of the binary. But one of the most distinctive signatures of an IP is what's called the beat period.

The beat period is the time it takes for the white dwarf to rotate once relative to its binary companion and not relative to space. Because the two stars move around each other, one rotation of the white dwarf does not bring it back to the same position relative to the companion star — it always has to rotate just a little more to catch up with the companion. (For the same reason, it takes Earth 23 hours and 56 minutes to rotate once relative to the background stars but an extra four minutes to return to the same position relative to the sun.) If radiation from the white dwarf reflects off the red dwarf, for example, it will vary at the beat period. Because the variations in the light of an intermediate polar can exhibit at least three periods — spin, orbital, and beat — IPs are observationally distinct from other cataclysmic variables.

Still, astronomers debate exactly what these systems look like and how they differ from nonmagnetic CVs. Although the magnetic field certainly affects the accretion disk, no one knows the severity of that effect. If the orbital period is fairly long — say more than four or five hours — or the magnetic field is less than around a million gauss, an accretion disk will likely begin to grow as usual but have its center disrupted by magnetic forces.

The magnetic field acts on the disk a bit like a rotary whisk in cake mixture, sweeping out the gas in the center and leading to a disk with a central hole centered on the white dwarf. Gas from the inner edge of the surrounding narrow ring then attaches itself to the magnetic field and plummets at supersonic velocities toward the white dwarf. When it hits the star's surface, its kinetic energy gets converted to radiant energy and gets blasted away as x rays.

If the strength of the magnetic field rises above a certain threshold or the binary separation is slightly tighter, however, the magnetic field will prevent a disk from forming at all. Some IPs may well lack disks. If so, they would share this distinction with an even more extreme subclass of cataclysmic variable, the polars.

The Extreme Stars

Not long after astronomers unearthed the secrets of DQ Herculis, another star system in Hercules started to garner attention. In the March 15, 1977, edition of *Astrophysical Journal Letters*, no fewer than four articles concerned a source called AM Herculis, discovered as a novalike variable in 1924. In the last of these papers, Santiago Tapia of the University of Arizona reported that the system showed a polarization that varied periodically.

The white dwarf in a polar CV has such a strong magnetic field that no accretion disk forms and gas flows straight to the white dwarf's poles.

Here was another magnetic binary, but this one had a startling twist: The light was so highly polarized that it implied a magnetic field strength of 200 million gauss — 100 times greater than in DQ Herculis and 400 million times the strength of Earth's. Although astronomers eventually realized that the field strength had been significantly overestimated, they still rank it as perhaps 30 times greater than in DQ Herculis. Since 1977, some 70 other systems have been discovered with similarly strong magnetic fields. These are the AM Herculis stars — also called polars because of their high polarization levels — the most recent significant subclass of cataclysmic variable.

Polars have even more profound effects than intermediate polars. The magnetic fields are so strong — typically 30 million gauss but ranging as high as 230 million gauss in one system — that their influences are felt as far out as the companion star. Imagine the secondary as made of molasses, and the magnetic field to be loops of wire. As those wires rotate, they are dragged through the molasses and start to get stuck. This slows down the rotation until, eventually, it stops completely. What results is a binary system where the white dwarf's magnetic field lodges in the atmosphere of its companion so that, as the red dwarf orbits, the white dwarf is forced to rotate with it. In the same way that the moon keeps the same face toward Earth, each of the two stars keeps the same face toward the other, and the whole system of stars and flowing gas essentially rotates as a solid body.

Gas slipping away from the red dwarf's atmosphere gets seized by the magnetic field soon after it becomes free and can't circle the white dwarf to form an accretion disk. Instead, it flows like a gigantic auroral arc along the magnetic field lines from the surface of the red star directly to the white dwarf's magnetic poles. Moreover, because the white dwarf has essentially stopped rotating relative to its companion, the radiation from most polars varies only with the orbital period — there is no separate spin or beat period. These cataclysmic variables appear unlike any other.

Toys of the Future

Some magnetic CVs are among the most luminous x-ray objects in the sky and generally are easier to spot with instruments sensitive to high-energy radiation. So not surprisingly, the number of cataloged magnetic systems has grown significantly since the advent of x-ray and ultraviolet satellites. The latest catalog of cataclysmic variables lists more than 1,000 objects, of which more than 800 are bona fide CVs and some 10 percent are known to contain a highly magnetic white dwarf. Indeed, all may be magnetic to at least some degree.

With more and better space-borne observatories now than ever before, discoveries are flooding in on a monthly basis. Perhaps, out there in space, another subclass of cataclysmic variables — magnetic or not — with wholly unexpected characteristics awaits discovery. But in the meantime, astrophysicists have more than enough toys to keep them happy.

Mark A. Garlick is a freelance writer, space artist, and former astronomer based in Brighton on England's south coast. More of his images can be found online at http://www.space-art.co.uk.

Making the Stars

Under a cloak of Star Wars secrecy,
Robert Fugate and his team
developed the means to de-twinkle the stars.

by Mark Sincell

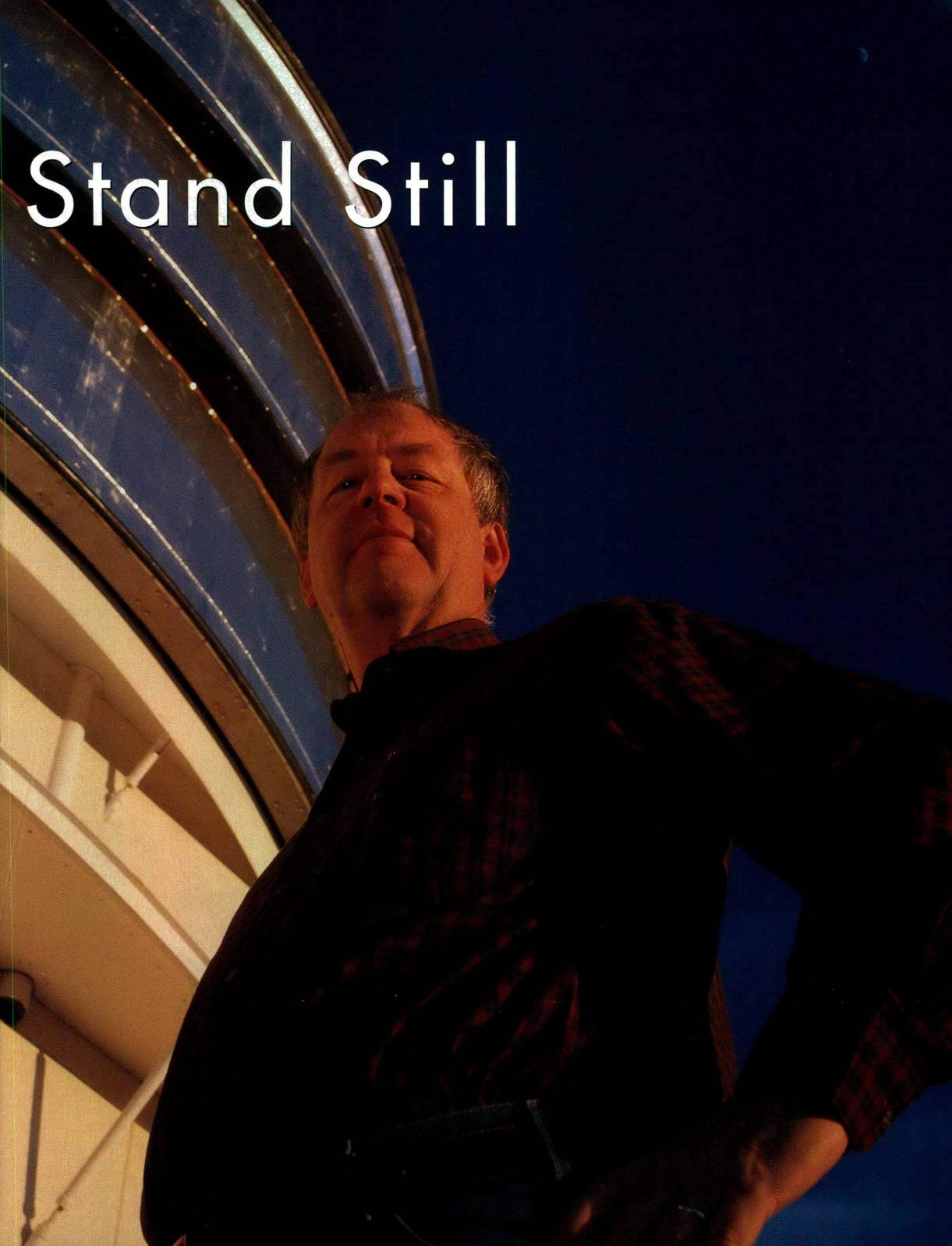
Robert Fugate works nights. Lots of them. It's a habit he picked up at an early age. For his 1961 senior-year science project at Belmont High School in Dayton, Ohio, Fugate spent more than 1,000 extracurricular hours building electroluminescent display panels — a primitive forerunner of the modern laptop computer screen. The Westinghouse Science Talent Search was so impressed with his creations they awarded him a cruise on a minesweeper, courtesy of the United States Navy.

Hooked by that first thrill of discovery, Fugate has kept up a torrid research pace for the last four decades. Working day and night at the Air Force Research Lab's Starfire Optical Range on the Kirtland Air Force Base outside Albuquerque, New Mexico, Fugate turned a skeptical colleague's equations into the first fully functional adaptive optics telescope.

Robert Fugate stands next to the Starfire Optical Range's 3.5-meter telescope.

All photos of Robert Fugate by Rose Palmisano and Pat Vasquez-Cunningham

Stand Still



Fugate's work started a revolution in ground-based optical astronomy, and now virtually every major professional telescope in the world uses a variant of Fugate's original adaptive optics system to compensate for atmospheric turbulence and "de-twinkle" the stars. "It couldn't have happened without Bob," says Princeton physicist Will Happer, who has known Fugate since the conception of the Starfire project. "He is a world-class scientist, an honest man, and very persuasive."

EARLY YEARS

Bob Fugate didn't start out trying to solve astronomy's centuries-old problem of atmospheric blurring. His scientific career began at the side of his father, Arthur, first as a 9-year-old ham radio operator and later as a backyard astronomer. After high school, Fugate turned down a full-ride engineering scholarship to the University of Cincinnati so he could study physics at the Case Institute of Technology (which is now part of Case Western Reserve University in Cleveland, Ohio). Without a scholarship, his parents had to foot the bill. "It was what I wanted to do and they sacrificed to support me," says Fugate.

After graduation, Fugate married his college sweetheart, Marilyn Moritz, and then enrolled in the physics graduate program at Iowa State University. There he completed a Ph.D. in experimental low-temperature solid-state physics. Fugate's advisor, Clayton Swenson, had no doubt that Fugate would become a top-flight scientist: "He was a superb experimentalist, with a knack for appreciating and understanding hardware problems and for finding innovative and workable solutions."

U.S. Air Force Research Laboratory, Directed Energy Directorate, Starfire Optical Range

Despite his stellar record and obvious potential as a scientist, the end of graduate school found Fugate in a position all too familiar to the modern-day grad student: looking for work. "In 1970, there was a glut of physics Ph.D.s on the market," explains Fugate, "It was nearly impossible to find a job."

Then fate stepped in . . . to the beauty parlor.

In April 1970, Fugate's mother-in-law Velma Moritz, who owns a beauty salon, was speaking with one of her clients. The client mentioned that her husband, an Air Force engineer, was looking to hire a young physicist for the Foreign Technology Division at nearby Wright-Patterson Air Force Base in Dayton. Fugate called, got an interview, and a few months later found himself studying how aerosol particles in the atmosphere scatter laser light. Although Fugate admits to knowing little about the subject initially, "I knew how to do research," he says.

In 1978, Fugate's friend and fellow Wright-Patterson physicist Ron Grotbeck was transferred to Kirtland Air Force Base to work in the pulsed electric discharge laser group. "We didn't have an optics person," recalls Grotbeck. "I wrote up a job description. But I wasn't in any hurry to fill it." That is, until Fugate called to say hello. "I told him, 'We really need someone like you down here.'" By the end of 1979, Fugate was working at the Sandia Optical Range (Fugate renamed it the Starfire Optical Range, which operates under the Air Force Research Laboratory's Directed Energy Directorate).

Fugate immediately began studying how the atmosphere affected laser propagation, but his research was about to take a surprising turn.

BIRTH OF ADAPTIVE OPTICS

In 1980, physicist Julius Feinleib was standing at the summit of Haleakala, an extinct volcano on the Hawaiian island of Maui. Feinleib was observing a demonstration of lidar (short for

The Starfire adaptive optics system uses lasers to create artificial stars. By observing how the atmosphere distorts the artificial star, computers and deformable secondary mirrors compensate for turbulence.

"light radar"), a laser system used by the military to measure atmospheric transparency. As he watched the laser beam cut through the night sky, Feinleib had an idea. Some of the laser light was reflected by molecules in the atmosphere and returned to Earth. This reflected light carried a detailed map of the atmospheric turbulence along the light path. What if a detector could read this map? Conceivably, that map could remove the distorting effects of the atmosphere that plagued U.S. Air Force attempts to photograph Soviet satellites. Or maybe it could "pre-distort" a laser beam so that all the laser's energy could be focused on enemy satellites in order to shoot them down.

To correct for the atmospheric distortion of a telescopic image of a passing satellite, one could shoot a laser beam at a point near the satellite and gather the reflected light in a detector, called a wavefront sensor. The sensor instantaneously unravels the pattern of atmospheric turbulence imprinted on the image of the artificial "laser guide star" and passes this information to a computer-controlled deformable mirror. The computer tells hundreds of tiny pistons on the back of the mirror exactly how much to bend the mirror to compensate for the turbulence. The idea is simple, but would it work?

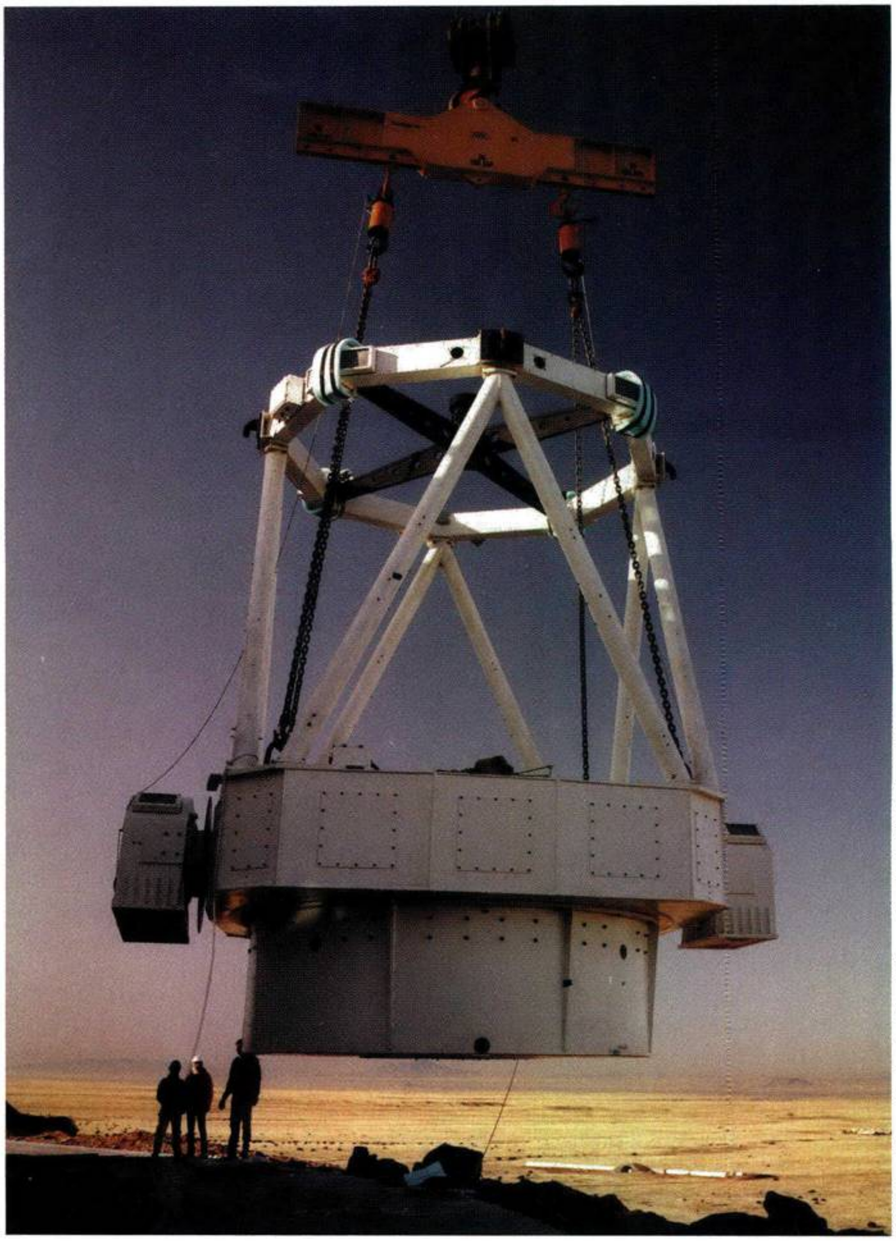
David Fried, a physicist who advised the Air Force on classified research projects, didn't think so. Fried had his first contact with both Bob Fugate and adaptive optics when Feinleib presented his laser guide star idea to a 1981 meeting of the Defense Advanced Research Projects Agency (DARPA) in Washington, D.C. "To get rid of Feinleib, I did the analysis to prove he was wrong," says Fried. An all-nighter at the hotel produced the equations, but they were too complicated to solve by hand. So Fried had to wait until he returned to his offices in California. When his computer finished crunching, Fried got a surprise. "I proved he was right," he says.

In the summer of 1982, the Starfire project was born. A specially selected group of civilian scientists reviewed Feinleib's proposal and advised the Air Force and DARPA to proceed with research on the laser guide star method. All that remained was to find a scientist to turn the concept into a working system. The Air Force turned to Fugate because, in the words of retired Air Force General Don Lamberson, the Air Force's senior technologist at the time, "He takes the trouble to understand the needs of the Air Force."

"When we started, we didn't even have a telescope," recalls Fugate, "just a 16-inch off-axis parabolic mirror and a 24-inch flat mirror." But one year and $100,000 later, Fugate's team of five Air Force scientists and engineers successfully used a laser guide star to reconstruct the distorted wavefront of light from Polaris. Nearly 20 years later, Fugate still sounds excited, and slightly amazed, when he recalls, "It worked exactly as the theory predicted!"

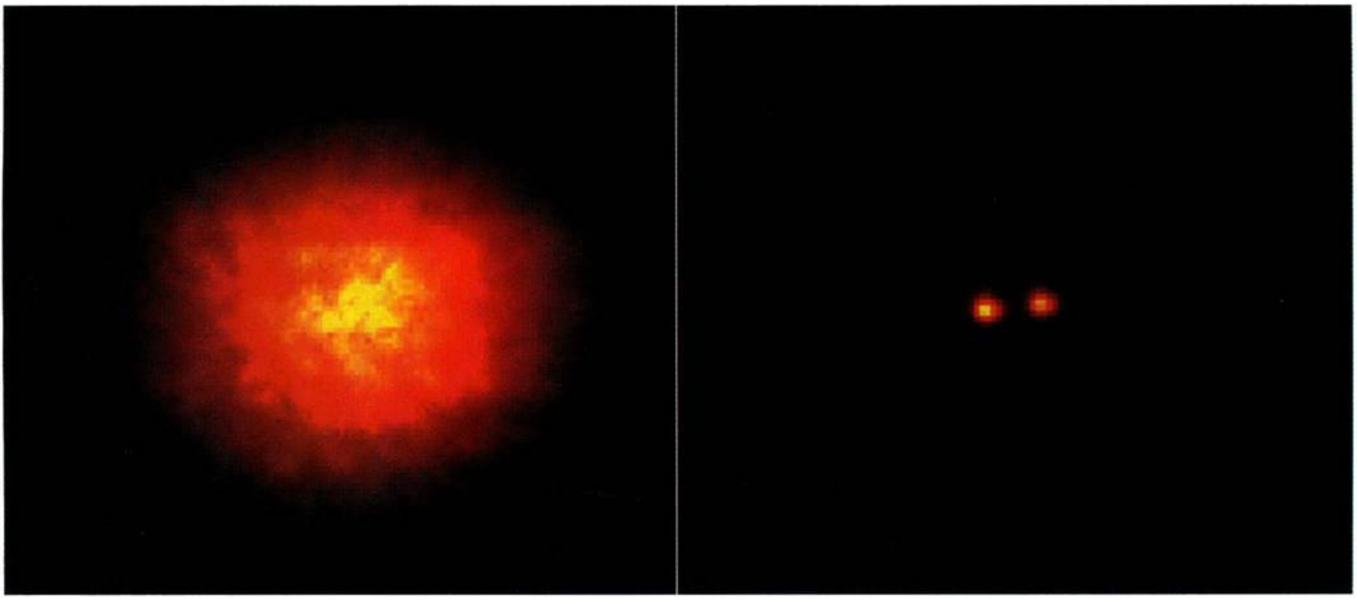
STRATEGIC SCIENCE

Despite his early success, Fugate still had to hustle for money to keep the project running. By 1984, the Strategic Defense Initiative (also known as SDI, or "Star Wars") had control of the project's purse strings. So Fugate went to Washington to ask the Air Force and SDI to invest in development of a full-scale adaptive optics system on a 1.5-meter telescope. Fugate's research intrigued the Star Wars strategists for two reasons. He was learning how to keep a laser beam focused as it passed through the atmosphere, and he was developing a telescope capable of photographing Soviet spy satellites. They believed that both techniques could potentially help Star Wars accomplish its goal of knocking incoming



U.S. Air Force Research Laboratory, Directed Energy Directorate, Starfire Optical Range

In 1993, technicians installed a 3.5-meter telescope at the Starfire Optical Range near Albuquerque, New Mexico. Fugate uses this telescope to improve adaptive optics.



U.S. Air Force Research Laboratory, Directed Energy Directorate, Starfire Optical Range

U.S. Air Force Research Laboratory, Directed Energy Directorate, Starfire Optical Range

A binary star imaged without adaptive optics (left) appears as an amorphous blob. The same telescope using adaptive optics (right) easily resolves the two stars.

nuclear-tipped missiles out of the sky with a well-directed beam of light.

The Air Force and SDI gave him $1 million to build his telescope. But there was one condition: Starfire had to remain classified.

The 1.5-meter telescope arrived in 1987, and Fugate set to work with his usual zeal. By this time, his team had grown to about 30 scientists, engineers, and technicians. When he wasn't in Washington explaining his work to Air Force officials, he was working around the clock with his team designing and building equipment, refining the guide star method, and observing the stars and passing satellites. "He would usually come home while I was doing my morning paper route," recalls Fugate's son, Jeff, "and then we would meet up again for dinner and homework before he went back to work. I'm not sure when he slept."

While Fugate's hours may have seemed strange to Jeff and his sister, Elizabeth, they were particularly tough on his wife, Marilyn. "Marilyn is one in a million," says Fugate. "She doesn't know when or if I will be home for dinner, when I might get up and go into work, and what fraction of the weekend I will work. For a while, and maybe even now, she kept track of how much extra time I worked. I always wonder what she is going to do with this data."

The hard work paid off. By February 1989, Fugate's team had created the first laser-guided, deformable-mirror adaptive optics telescope in the world that continuously corrected the blurring effects of atmospheric turbulence. And no one outside the military had *any* idea it existed.

DECLASSIFICATION

Julius Feinleib wasn't the only scientist to be inspired by a lidar demonstration. Across the globe, two French civilian astronomers watched a lidar laser beam shoot out over the French Alps and reached the same conclusion: Laser-guided adaptive optics could correct for atmospheric turbulence. But instead of photographing satellites, Reynaud Foy and Antoine Labeyrie published a paper in 1985 describing how adaptive optics could "de-twinkle" the stars.

Building on Foy and Labeyrie's work, University of Illinois astronomer Laird Thompson completed an engineering design study for a laser-guided adaptive optics system that he would later discover was virtually identical to Starfire. But Thompson never got a chance to build his system. Although he submitted several funding proposals, says Thompson, "I was turned down by referees who said it wouldn't work."

Inside the military, however, Fugate's small group knew it would work. When a London-based military attaché assigned to keep an eye on academe came across Thompson's published design study, he sent a report back to the Pentagon, triggering a chain of events that eventually pushed Starfire into the public eye.

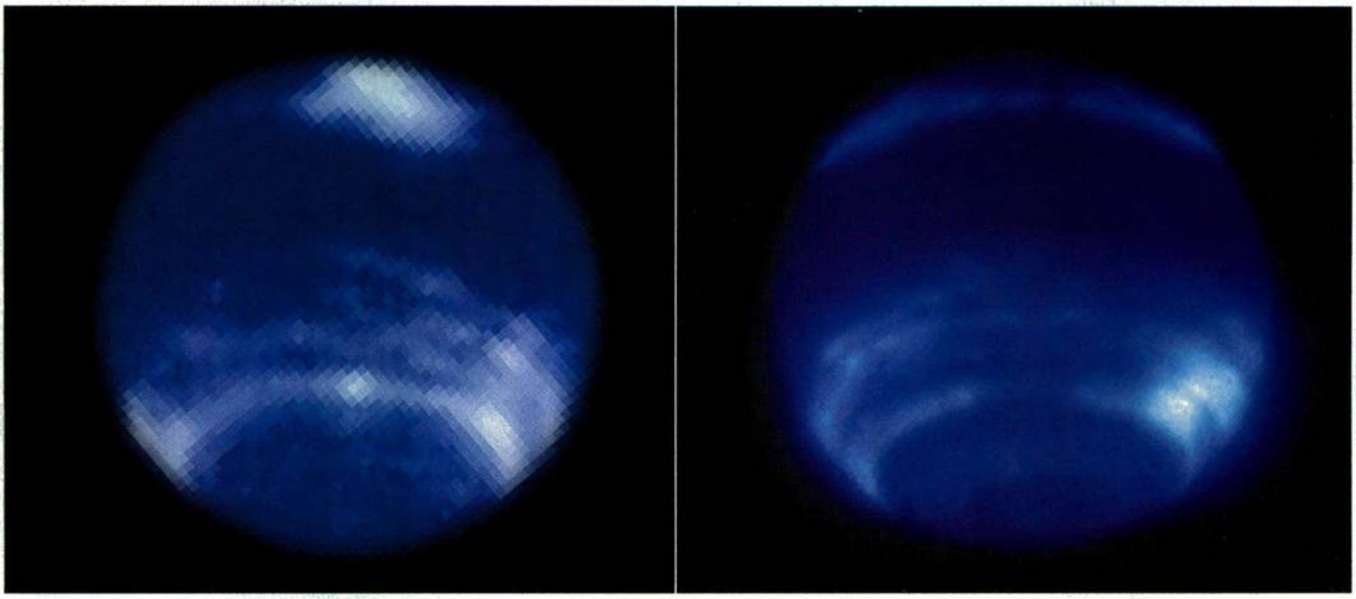
"It was painful to realize how far Starfire had gone before civilians even knew about it," says Will Happer, who, as a member of the civilian committee that recommended beginning the Starfire adaptive optics program, knew about the group's rapid progress. So Happer, Fugate, and Lawrence Livermore National Laboratory astrophysicist Claire Max began pushing to declassify Starfire's adaptive optics. "It was clear that the civilian community was on the way to developing its own systems," says Happer.

It took two years and hundreds of letters to convince the Air Force, but by the spring of 1991, declassification looked imminent. So Fugate, at the invitation of Nobel laureate physicist Charles Townes, who had been following Starfire's progress, sent in a one-line title announcing a talk on adaptive optics at the May 1991 meeting of the American Astronomical Society in Seattle, Washington.

SEATTLE, 1991

Even though the disintegration of the Soviet Union had recently ended the Cold War, concern over the potential military value of Starfire delayed final approval for declassification. "We needed a very high level of approval, above the Air Force," says Fugate, who speculates that either Secretary of Defense Dick Cheney or President George Bush ultimately made the decision to declassify Starfire.

While he waited, and the Seattle meeting drew nearer, Fugate had to keep quiet. "A few people called to ask about the title," says Fugate, "But I



A near-infrared image of Neptune taken on the ground with the Keck Telescope with adaptive optics (right) is just as sharp as a near-infrared image of Neptune taken with the Hubble Space Telescope (left).

Lawrence Sromovsky, Patrick Fry (University of Wisconsin), and NASA

Claire Max / Lawrence Livermore National Lab. / W.M. Keck Observatory Adaptive Optics Team

couldn't talk." Finally, on the Friday before his Sunday departure for Seattle, Fugate got the word: Declassification was a go.

Before he arrived in Seattle, Fugate had never talked to more than 20 people at a time. So he was understandably surprised when more than 600 astronomers showed up for his presentation. "It was standing room only," says Fugate. "I felt really nervous because I wasn't used to talking to such a large group." But he pressed on, much to the delight of his audience.

The response to Fugate's talk was nearly unanimous. "I was elated," recalls Max, "and 95 percent of the crowd was impressed and elated, too." The remaining 5 percent were a bit resentful, says Max, who speculates that perhaps they were wondering what they could have done if they had only known earlier. For his part, Thompson found Fugate's talk "both exhilarating and depressing." It was almost haunting to see the system he had proposed, and been denied funding to build, actually working. "But I was elated that it could be done," he adds.

Fugate's announcement spread rapidly through the astronomy community, and soon everyone knew that adaptive optics not only could be done, it already had been done. "You didn't have to be there to feel the impact," says Seattle no-show and telescope builder extraordinaire Roger Angel, the head of the University of Arizona's Mirror Laboratory. "Fugate is a real revolutionary. Lots of people wouldn't have had the guts to innovate as he did."

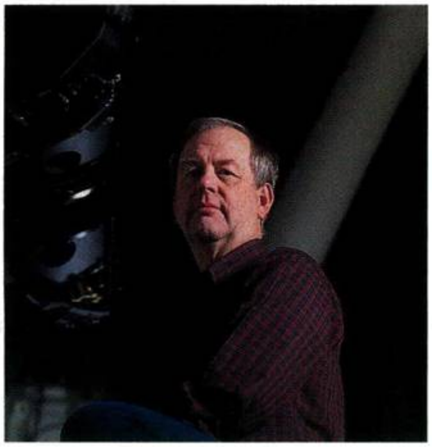
Fugate used declassification to establish fruitful collaborations with other scientists. "He is a true gentleman," says Thompson, "He shares ideas, invites people to visit, and opens doors."

SURPASSING HUBBLE

Whatever fears the Air Force may have had about declassifying the Starfire's adaptive optics system vanished in the wake of the tremendous innovation inspired by Fugate's work. "Declassification paid enormous dividends to the Air Force," says General Lamberson. "Civilian participation opened up entirely new vistas of ideas and concepts," adds Fugate, including new mirrors, cameras, and miniaturization techniques.

Not to mention telescopes. Within the next few years, giants such as the twin Keck 10-meter telescopes, the Japanese 8.3-meter Subaru Telescope, the Large Binocular Telescope, and the twin Gemini 8.1-meter telescopes will use adaptive optics systems to surpass the resolution of the Hubble Space Telescope — from the ground. The potent combination of high resolution and unprecedented light-gathering power should dramatically increase the pace of scientific discovery, and one of these telescopes is almost certain to snap the first picture of a planet outside the solar system (see "Sharpening the Stars," January 1998).

Robert Fugate's research has sparked a revolution in ground-based optical astronomy.

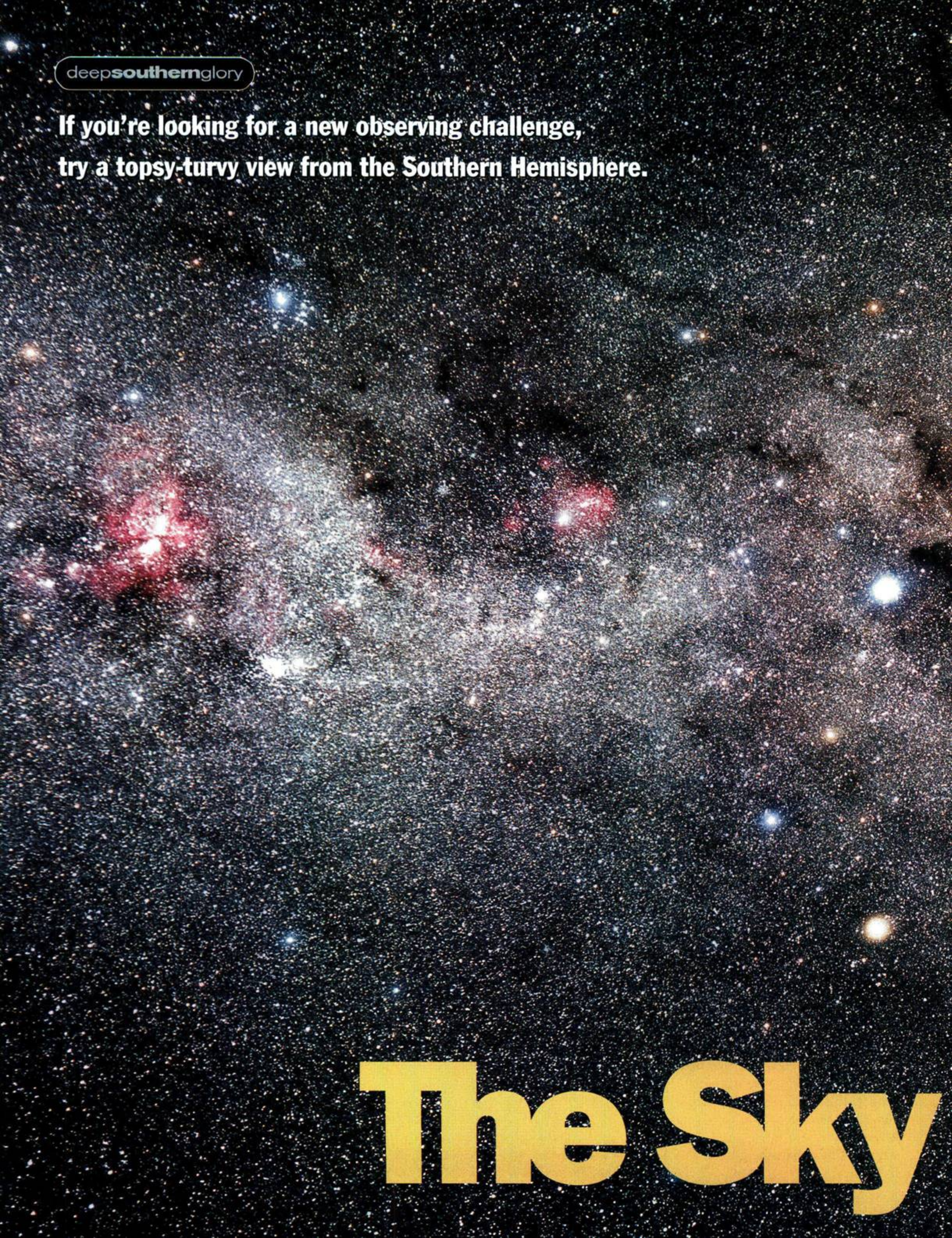


But perhaps the greatest irony of Bob Fugate's story is how little of his time is now devoted to astronomy. Fugate estimates that 95 percent of his time is spent on classified military applications of adaptive optics, leaving only 5 percent for astronomy. But Fugate isn't shedding any tears; he has too much work left to do. ◼

Mark Sincell is a freelance writer based in Houston, Texas. His previous article for Astronomy *was "Switched at Birth" in the March 2000 issue.*

To learn more about Starfire and Robert Fugate's research, visit wwwsor.plk.af.mil/default.htm.

If you're looking for a new observing challenge, try a topsy-turvy view from the Southern Hemisphere.



The Sky

Down Under

By Fred Ringwald

When Bart Bok left Harvard to direct Mount Stromlo Observatory in Australia he said, "All of the good stuff is in the Southern Hemisphere." For someone who lives in the Northern Hemisphere, the first observing session from the Southern Hemisphere is an epiphany. My defining moment came when I had the opportunity — the first time since I was eight years old — to learn 20 or 30 new constellations at once.

The fun begins during the daytime. From the Southern Hemisphere, the sun still rises in the East and sets in the West, but it moves from right to left across the northern sky. So does the moon, whose features are rotated 180°. When we first arrived in Chile, a friend remarked that the moon was upside down. I said, "No, you're upside down." The planets also move across the northern sky, and the equatorial constellations are upside down. I could still recognize some of the constellations easily, such as Orion, Delphinus, and Capricornus. Others, such as Ophiuchus or Cetus, I didn't recognize at all, until I worked them out with a star map.

When to Visit

A good time of year for your Southern Hemisphere observing adventure is between May and July, during the southern (or austral) midwinter. Constellations such as Sagittarius the Archer and Scorpius the Scorpion pass dramatically overhead. So does the Milky Way. This edge-on, barred spiral galaxy's galactic bulge is plainly visible on clear, dark nights.

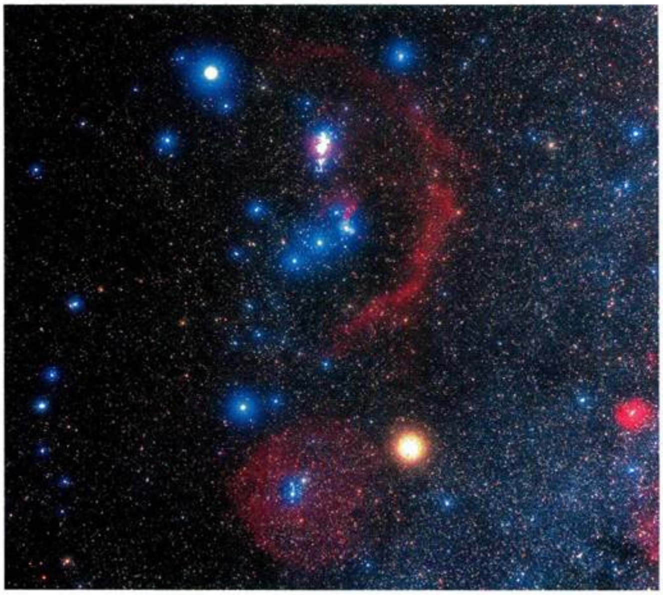
In May, one can see the lower third of the southern Milky Way (from Scorpius to Orion) in its entirety. This is the section we never see from the Northern Hemisphere. Following the Milky Way south from its center in Sagittarius, south and east through Scorpius, leads you to the large, bright constellation Centaurus the Centaur. Centaurus is too far south to be seen by most northern observers. This is unfortunate, because Centaurus is one of the grandest constellations in the sky, ranking right up with Orion. The mythological Centaur is depicted as spearing Lupus the Wolf, another large, bright constellation that extends into the Milky Way.

The two brightest stars in Centaurus are 1st-magnitude Alpha (α) and Beta (β) Centauri. Alpha is an easy visual double star through small telescopes, and its brighter, yellow component is much like the sun. Following Alpha and Beta Centauri westward along the Milky Way leads to the Southern Cross. To remember this path, just remember your ABCs, "Alpha, Beta, and the Cross." Northward from Alpha and Beta Centauri is Omega (ω) Centauri, by far the largest, brightest, and grandest globular cluster in the sky. M13, the famous northern globular in Hercules, falls a paltry third behind Omega Centauri and 47 Tucanae, which is also in the south.

At 4th magnitude, Omega Centauri is an easy naked-eye object. Through binoculars, one can resolve stars right through to the center, and it gets even better. The stars in Omega Centauri are bright enough that a view through a 16-inch telescope provides enough light to activate color vision. The stars reveal their topaz, orange, and red glory. Seeing Omega Centauri in black-and-white is similar to looking at a picture of the Grand Canyon. The real thing is far more spectacular.

The Southern Cross, or Crux, lies in a dense region of the Milky Way. I once read the remark: "What's so special about the Southern Cross? It's the smallest constellation, and it consists of only five or so stars." Whoever wrote these lines couldn't possibly have seen the constellation. Crux is striking, a real jewel box. Three of the stars shine at 1st magnitude, the others at 3rd magnitude. The Southern Cross is distinctive, in a league with Orion's belt and little else. It's also adjacent to the remarkably dark Coalsack, an apparent hole in the Milky Way about 5° across. The Coalsack is actually an interstellar dust cloud that blocks the light from stars behind it. Because it's surrounded by a host of stars in the Milky Way, the black patch appears darker. The Coalsack is unlike any other dark region in the sky.

Preceding page: The southern Milky Way holds such contrasting gems as the Eta Carinae Nebula (left center) and the Coal Sack (center). Luke Dodd



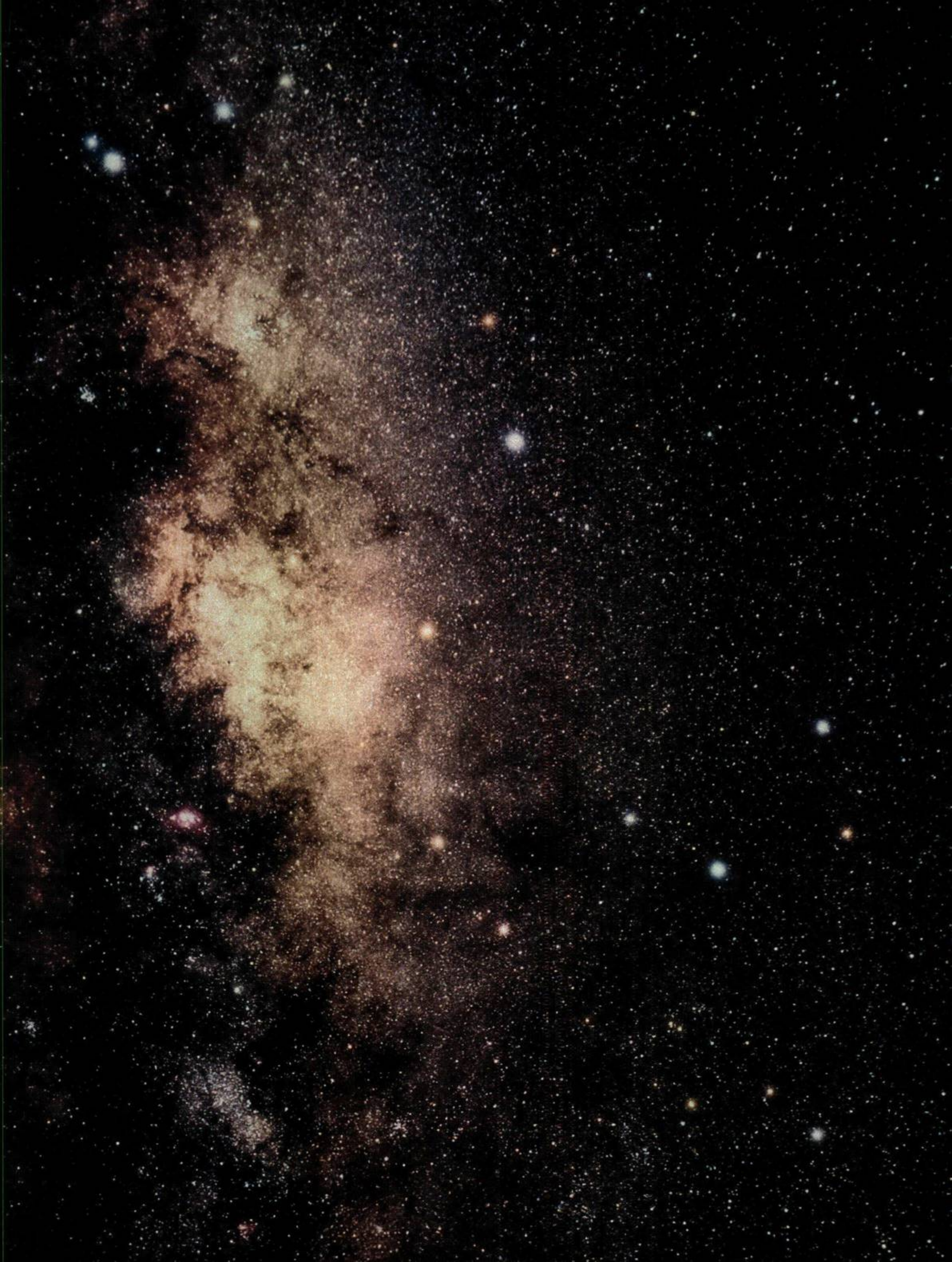
Above: To Southern Hemisphere observers, the mighty hunter, Orion, appears to stand on his head. Bill and Sally Fletcher

Right: The Teapot asterism in Sagittarius is hard to spot when the view is south up. One consolation: the Milky Way splendors in Sagittarius pass high above the horizon when on the meridian. Luke Dodd

Just north of the Coalsack is Beta Crucis, the 1st-magnitude star on the eastern end of the cross's crossbar. Between Beta Crucis and the Coalsack is the Jewel Box, or Kappa (κ) Crucis. An open cluster of more than 100 stars, the Jewel Box is more colorful than any similar object in the Northern Hemisphere.

Farther west along the southern Milky Way is the antiquated constellation Argo Navis the Ship. In the mid-18th century, the Great Ship was broken into four separate constellations: Carina the Keel, Vela the Sail, Pyxis the Compass, and Puppis the Stern (also known as the poop deck). I can never find Pyxis, it has only two or three faint stars, but Carina, Vela, and Puppis are bright, easy to spot, and extend far from the galactic plane.

If you follow the line from Alpha and Beta Centauri to the Southern Cross and then continue along the galactic plane about the same distance, you'll come to 5th-magnitude Eta (η) Carinae. In 1843, Eta Carinae had an outburst that made it the second-brightest star in the night sky. The eruption threw off most of a large nebula surrounding the star. This star is brightening again (see "Scoping Out the Monster Star," February 2000). The chance to witness an outburst makes any time you invest in monitoring the star worthwhile. The nebula around Eta Carinae is roughly 2° across (about four times the apparent diameter of the moon) and an easy naked-eye object that doesn't require skies as dark as those needed to see the North America Nebula in Cygnus the Swan. Like the North America Nebula, the Eta Carinae Nebula looks like it does in wide-field



Above: South (up) of the stars Alpha and Beta Muscae is a "globular filament" type of dark nebula nicknamed the Dark Doodad. Luke Dodd
Left: Viewing Scorpius and its deep-sky objects high above the murky horizon is a real treat for Northern Hemisphere observers. Luke Dodd

photos. The only difference is that the eye sees a ghostly white and not the garish red that film brings out.

Continuing west along the Milky Way, from Alpha and Beta Centauri to Crux past Eta Carinae, we come to an area between Vela and Carina. Here lies an asterism called the False Cross. It's about the same size and shape as Crux, but not as bright, having "only" three 2nd-magnitude stars (Delta [δ] Velorum and Epsilon [ε] and Iota [ι] Carinae), and one 3rd-magnitude star (Kappa Velorum).

Canopus, the second brightest star in the sky, is at the end of the handle of Carina the Keel. Sirius, the brightest star, is farther west and north along the Milky Way in Canis Major. Here too is familiar Orion. His upside-down figure appears awkward with Lepus the Hare resting above his feet. South of Lepus rests Columba (not Columbia) the Dove.

Looking away from the southern Milky Way, we find two of the largest constellations in the sky: Eridanus the River and Hydra the mythical Water Snake. Both are long, thin, and wind their way around the sky similar to the north-circumpolar constellation Draco the Dragon.

Eridanus is distinctive where it begins near Orion's feet. After that, the constellation's meanderings are hard to follow. The River winds its way southward past the claws of Cetus the Whale and around Fornax the Furnace toward an unmistakable end at the 1st-magnitude star, Achernar.

Hydra also holds mainly faint stars, but it is worthwhile to spend the time puzzling out it's path with a star chart. The constellation begins in a small quadrilateral south of Leo and Cancer. From there it winds its way southward past Sextans the Sextant, Crater the Cup, and Corvus the Crow to its end near Centaurus. As the largest of 88 constellations, Hydra spans more than 100° of sky.

What's in a Name?

Many southern constellations were named during the 17th through 19th centuries. These recent additions reflect the scientific interests of that period. Constellations such as Horologium the Clock, Microscopium the Microscope, and Telescopium the Telescope are all faint and hard to find. Another, Octans the Octant, depicts an obsolete navigational instrument. Nearby, Mensa forms another grouping of faint stars. This constellation is named for Table Mountain near Cape Town, South Africa, where the southern sky was first surveyed in the 1820s. Mensa is the only constellation named for a geologic feature.

Small but distinctive Antlia the Air Pump takes us back toward the Milky Way. Air pumps were scientifically a big deal in the 1600s, since they contradicted Aristotle's dictum that nature abhorred a vacuum. The constellation is small and not unlike Delphinus the Dolphin in the northern Milky Way.

Though the list of constellations to be learned is impressive, deep-sky wonders also abound. The objects you've struggled to see in Sagittarius and Scorpius are high overhead in vivid splendor. The Trifid Nebula (M20) really does have those dust lanes that cut it into three parts. The Lagoon Nebula (M8) is spectacular to the naked eye. The view of M8 from southern latitudes rivals that of the Orion Nebula (M42). NGC 5128, an elliptical galaxy that is the optical counterpart to the radio galaxy Centaurus A, has a broad dust lane across its round face. Through the eyepiece of a 6-inch or larger telescope, the galaxy looks like the long exposure images taken with large telescopes. The Sombrero Galaxy (M104) in Virgo has a thinner dust lane. Through the eyepiece its large hat-like shape becomes apparent. It too looks like the pictures you've seen.

Two of the greatest marvels are the Large and Small Magellanic Clouds, both near declination –70° are south-circumpolar and only visible from the Southern Hemisphere. The Large Cloud is near Dorado the Swordfish; the Small Cloud is near Tucana the Toucan. Between these satellite galaxies of the Milky Way is the small, faint constellation Hydrus the Little Water Snake. Larger Hydra, its mate, is nowhere nearby. "Cloud Season" is October through December, or austral spring to early summer. During this time period, the Magellanic Clouds are impossible to miss. Even if you're unfamiliar with the southern constellations, you'll be able to pick out the Magellanic Clouds. Both are fairly large, bright areas separated a fair distance from the Milky Way.

The Large Cloud is about 5° across, roughly half the width of your fist at arm's length. The Small Cloud is about 2° across. Each is filled with wonderful binocular sights. Unequaled among more than 50 star clusters in the Large Cloud is the Tarantula Nebula (30 Doradus). This dense, star-forming region is brighter and larger than the Orion Nebula. The Tarantula Nebula gets its name from long, thin tendrils sticking out, not unlike those seen in deep images of M42.

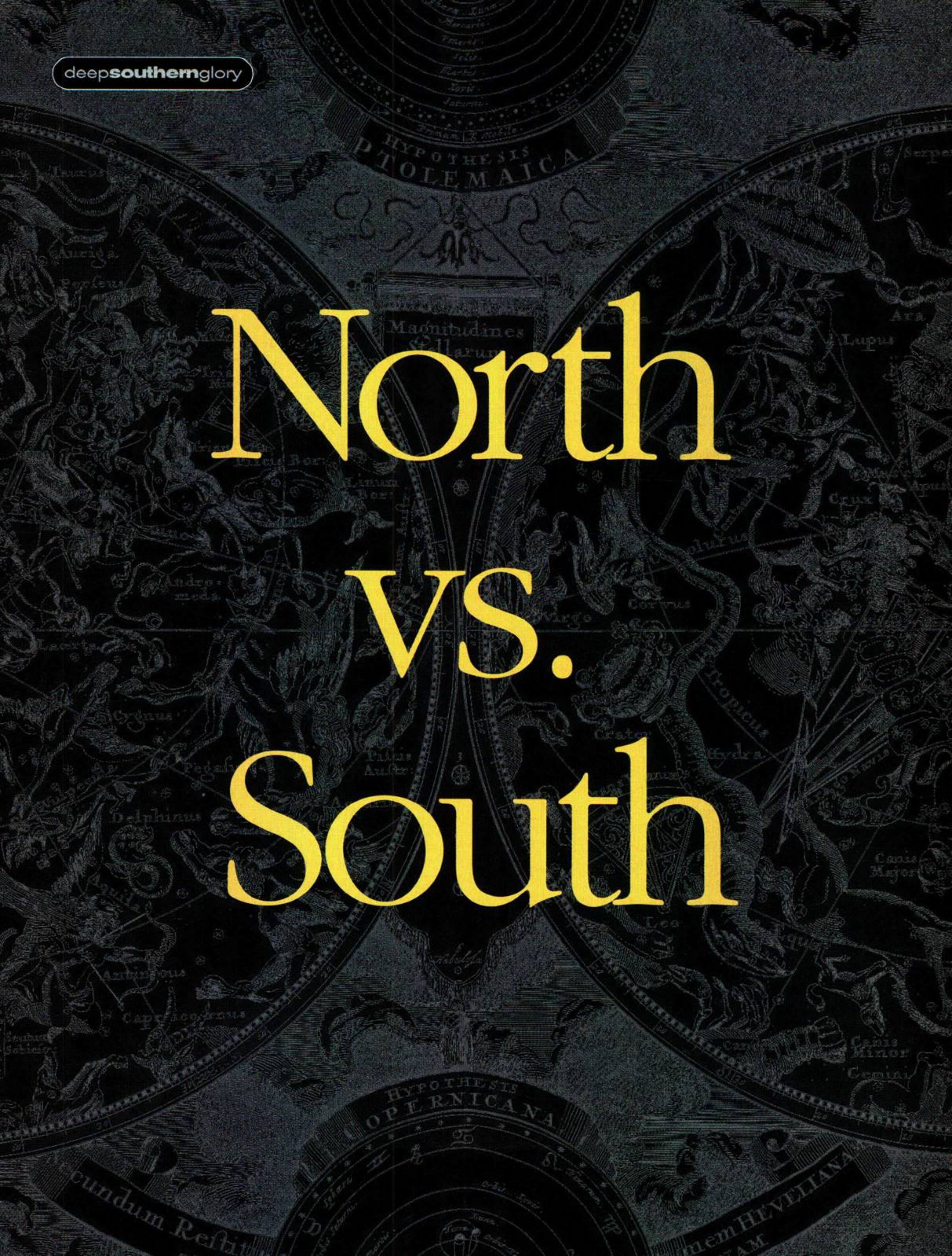
Pack Your Bags

If these sky views sound enticing, it's time to pack your binoculars and head south for the summer. You might want to plan your trip around one of the upcoming solar eclipses. On June 21, 2001, the eclipsed sun passes through Angola, Zambia, Zimbabwe, Mozambique, and Madagascar. On December 4, 2002, the sun's shadow falls on nearly the same region of Africa and also cuts across South Australia.

Whatever your itinerary, observing from the Southern Hemisphere will revive that initial exhilaration you felt when you first looked up. ■

Fred Ringwald is a faculty member at Florida Tech University.

North vs. South


HYPOTHESIS PTOLEMAICA
Magnitudines Stellarum
Auriga
Andromeda
Lacerta
Cygnus
Delphinus
Pegasus
Antinous
Capricornus
Lupus
Ara
Crux
Corvus
Virgo
Crater
Hydra
Tropicus
Canis Major
Canis Minor
Leo
HYPOTHESIS COPERNICANA

Which hemisphere holds the most beautiful sky objects?

by William Sheehan and Laurence Field

With few exceptions, astronomy books are written primarily for residents of the Northern Hemisphere. After all, most of the world's population lives north of the equator. But in astronomical circles, the Southern Hemisphere has garnered a reputation for holding the richest treasures in the night sky.

The two of us, both expatriate American citizens, have spent time in New Zealand enjoying the beauty of the southern sky. We decided to imagine a kind of Civil War of the Skies. Is the South's reputation deserved? Which hemisphere has the more beautiful deep-sky objects?

To find out, we will award 5 points for the best individual object in each category, 3 points for second, and 1 point for third. We will also award 5 points for the hemisphere that has the best overall representation in each class. Our categories will include open clusters, globular clusters, planetary nebulae, emission nebulae, and galaxies. Clearly there is an element of subjectivity in any such rankings. We do not intend our choices to be authoritative. We only hope to provoke you to go out and see for yourself. Let the battle begin!

Open Clusters

In binoculars or small telescopes, open clusters often resemble swarms of diamonds or fireflies. The beloved Pleiades (M45, also known as the Seven Sisters) in Taurus is easily the best naked-eye open cluster. Though a northern object, it has also been revered by southerners — it is depicted in prehistoric Aboriginal art, not as seven stars (they didn't know that story) but as 13 (the number that keen-sighted individuals in really dark sites can make out). With a wide-field eyepiece, the Pleiades are wreathed in blue reflection nebulosity, of which the brightest patch (NGC 1435) surrounds the bright star Merope.

The Southern Hemisphere boasts its own version: the Southern Pleiades (IC 2602) in Carina. It's a fine, bright, naked-eye cluster consisting of about 30 widely scattered stars, centered on 3rd-magnitude Theta Carinae. Photographs show a swath of blue reflection nebulosity to further enhance the similarity to its northern counterpart.

Another southern showstopper is NGC 6231 in Scorpius. This cluster is remarkable for its brilliant O and B supergiant stars. If it was located as close as the Pleiades, its brightest members would appear as brilliant as Sirius.

Our short list of spectacular objects includes NGC 4755 (South), the splendid Jewel Box near Kappa Crucis. As one of the youngest clusters known, its brightest stars are some of the most luminous in the galaxy. Both the Jewel Box and its smaller neighbor, the Gem Cluster (NGC 3293) in Carina (South), are remarkable telescopic objects featuring a central row of three bright, colorful stars, including a red giant and two intensely hot blue stars. Another of the southern sky's brightest open clusters, NGC 3532 in Carina, is easily visible to the naked eye.

By now the North would seem to be in full retreat. But it brilliantly counterattacks with NGC 869 and NGC 884, the famed Double Cluster in Perseus. Although these magnificent young clusters lie close together within a 1° field and each appear about the same size and brightness, they are not physically associated.

The envelope please. The South easily wins the best overall category award. But in our opinion, the two best objects belong to the Northern sky: the Pleiades and the Double Cluster, which is unique because of its double-yolked brilliance. Third place is a three-way tie between NGC 3532 (South), the Gem Cluster (South), and NGC 6231 (South). The North, on the strength of its two superclusters, scores a narrow upset in this category.

Score after one event: North 8, South 6.

Globular Clusters

The distribution of the 147 known Milky Way globular clusters is strongly skewed toward the South. Here we find a magnificent globular the size of the full moon, Omega Centauri (NGC 5139). It is easily visible to the naked eye as a fuzzy patch. British astronomer John Herschel wrote that it is "beyond all comparison the richest and largest object of its kind in the heavens." Even a 3-inch telescope resolves it into stars.

We could live with the idea of giving the highest accolades to Omega Centauri. But our favorite is the large, bright 47 Tucanae (NGC 104) (South), located some 2.5° west of the Small Magellanic Cloud. This globular is more dazzling and brilliant due to its more concentrated core, contrasting with Omega's broader, more distributed core and dimmer disk.

Even M22 in Sagittarius (South) surpasses the best the North has to offer, the celebrated M13 in Hercules. M4 (South), easily found just 1.3° west of Antares, also rivals M13. To give some idea of just how feeble M13 is compared to its two great southern counterparts, consider the following: The rough diameters of Omega Centauri and 47 Tuc are 25' to 30'; M13 is a mere 10'. Omega and 47 Tuc are both 4th-magnitude objects, M13 is 6th. All three globulars contain about a million stars, but Omega Centauri and 47 Tuc are on the order of 15,000 light-years away compared to M13 at 25,000 light-years.

After M13, the finest northern globular is M5 in Serpens. The South boasts several more great globs, including NGC 6397 in Ara — possibly the closest of all to the solar system — and the grand but unjustly neglected NGC 6572 in Pavo, which is exceeded in apparent size only by the monsters Omega Centauri and 47 Tuc.

The envelope please. The best overall winner is easily the South. Individual places: First goes to 47 Tuc (South), second to Omega Centauri (South), and third to M22 (South). Honorable mentions but no points to M13 (North) and M4 (South). The South scores a clean sweep.

Score after two events: South 20, North 8.

Planetary Nebulae

Planetary nebulae are probably the most colorful objects in the deep sky. Large amateur telescopes reveal an assortment of luminous objects glowing in pale blues and greens, some round or annular, others "bipolar" (hourglass) in shape. Most are small.

The bipolar shape is seen most spectacularly in the North. The Dumbbell Nebula (M27) in Vulpecula, second brightest in the night sky (magnitude 7.4), is probably the most photographed of all. Even small telescopes reveal a clear hourglass shape.

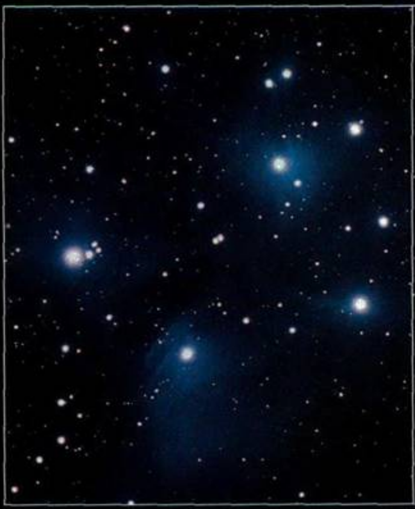
The easiest annular planetary is undoubtedly the celebrated Ring Nebula (M57) in Lyra (North). The Ring glows at magnitude 8.8. You can see its oval shape in a 4-inch scope and its central "hole" in 6- to 8-inch scopes. A southern pale disk to seek out is the larger and brighter (magnitude 8.0) NGC 246 in Cetus.

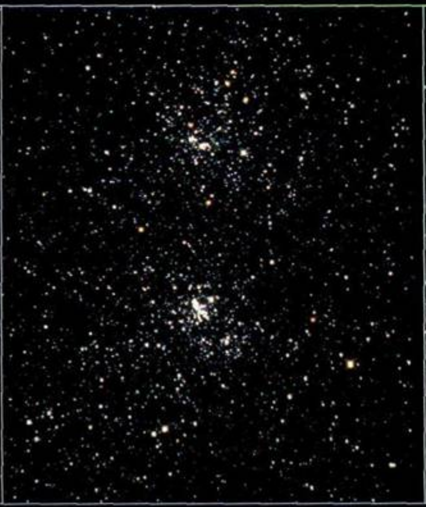
Technically, the South boasts the largest, brightest, and nearest planetary, the giant Helix Nebula (NGC 7293) in Aquarius (only 590 light-years away). But don't be deceived by its listed magnitude 6.5. All its light is distributed over its huge disk. To see it, you'll need a wide-field, low-power eyepiece and a very dark sky.

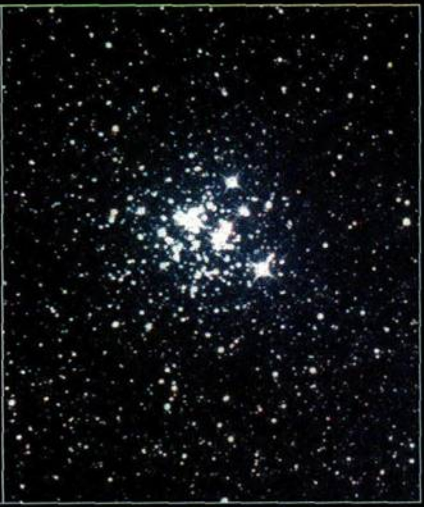
If you want to see color in planetaries, look to the smaller ones. Two of the most beautiful in the South are the Saturn Nebula (NGC 7009) in Aquarius, appearing turquoise on a good night and oval, and the bright Blue Planetary (NGC 3918), a small (15") blue disk in Centaurus near the border with Crux. A fine pale-blue planetary, NGC 3132 in Vela (South), is called the Eight Burst Nebula, named for its elliptical shape and condensed core with a central star. Two other excellent contenders, with visible internal structure, are the Ghost of Jupiter (NGC 3242) in Hydra (South) and the Eskimo Nebula (NGC 2392) in Gemini (North).

Top left to bottom right: Michael and Kelly-Ann Grady; Lee C. Coombs; Gregg Thompson; Robert Klyn; Andrew Peters; Kim Zussman; Chris Schur; Tim Hunter and James McGaha; Ken Blankenship and Dennis Batis

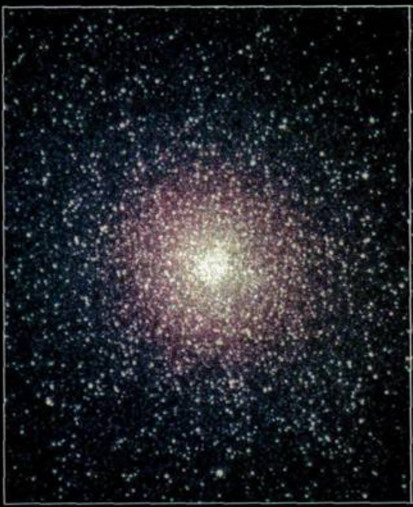
OPEN CLUSTERS

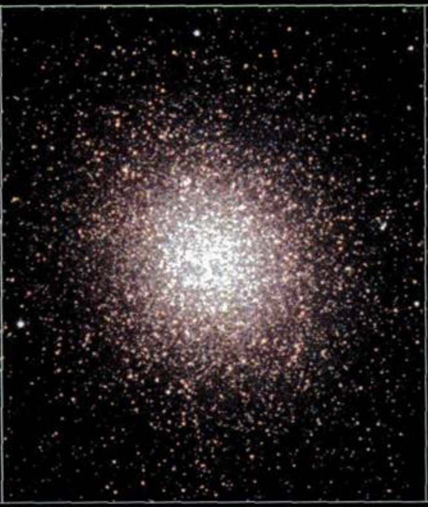

NORTH • THE PLEIADES (M45)

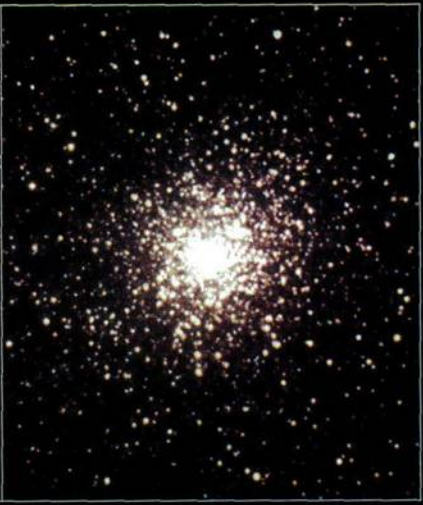

NORTH • DOUBLE CLUSTER (NGCs 869 AND 884)


SOUTH • JEWEL BOX (NGC 4755)

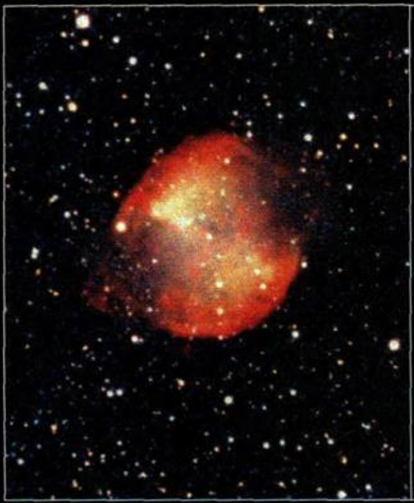
GLOBULAR CLUSTERS

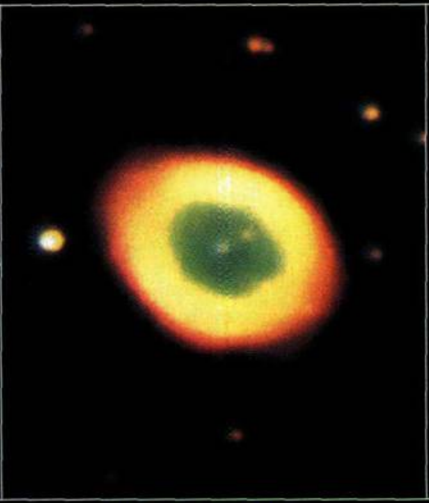

SOUTH • 47 TUCANAE (NGC 104)

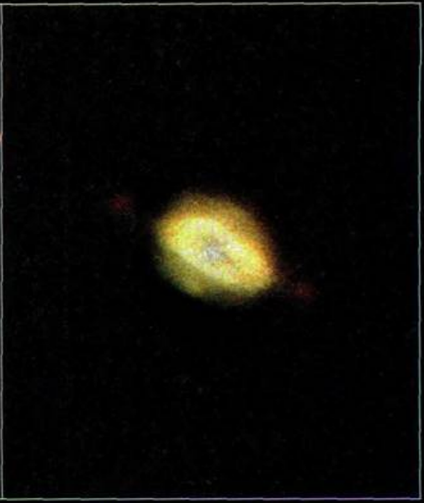

SOUTH • OMEGA CENTAURI (NGC 5139)


SOUTH • M22

PLANETARY NEBULAE


NORTH • DUMBBELL NEBULA (M27)


NORTH • RING NEBULA (M57)


SOUTH • SATURN NEBULA (NGC 7009)

EMISSION NEBULAE

NORTH/SOUTH • ORION NEBULA (M42)

SOUTH • ETA CARINAE NEBULA (NGC 3372)

SOUTH • TARANTULA NEBULA (NGC 2070)

GALAXIES

SOUTH • LARGE AND SMALL MAGELLANIC CLOUDS

NORTH • ANDROMEDA GALAXY (M31)

SOUTH • NGC 5128

Top left to bottom right: John Chumack; Michael Stecker; James R. Foster; Luke Dodd; Michael and Kelly-Ann Grady; Jack Marling

For the greatest variety, we award best overall to the South. For the most spectacular in anyone's telescope or binoculars, first prize goes to the Dumbbell Nebula (North). Second goes to the Ring Nebula (North). Third place goes to the South, for its bright, colorful Saturn, Ghost of Jupiter, and Eight-Burst nebulae, split equally.

Score after three events: South 26, North 16.

Emission Nebulae

To observers in the North, the brightest and boldest emission nebula is the Orion Nebula (M42). Technically, however, M42 is in the Southern Hemisphere. But it is so close to the celestial equator (declination –5°) that Northerners and Southerners have an almost equal share in its beauty. A naked-eye object, it grows from a phosphorescent glowing star in binoculars to a great fan of chaotic nebulosity in modest telescopes. The emission from the fluorescing hydrogen is so bright that the keen observer looking through a large scope can make out not only the obvious green but a more subdued salmon. The famous Trapezium quadruplet, including its primary, Theta^1 Orionis, illuminates the entire nebula from within and gives M42 its unique character.

While M42 is spectacular, it is far surpassed in size and brightness by the huge Eta Carinae Nebula (NGC 3372) in the brightest part of the southern Milky Way. This complex glowing cloud is split by two major dust lanes into nearly a square degree of nebulous light. Beautiful almost beyond compare, the outer wisps and tortuous veils grow centrally into brightly lit regions converging onto the orangish parent star Eta Carinae, which is one of the most luminous stars in the galaxy (see "Scoping Out the Monster Star," February 2000). At higher magnification, small, black twists and blobs of dust contrast with tiny brilliant clusters of stars set into the nebular light. An irregular dust cloud near Eta Carinae is called the "keyhole," which gives rise to the alternate name Keyhole Nebula.

Other beautiful and bright emission nebulae grace the southern Milky Way. These nebulae include the Lagoon Nebula (M8), the Omega Nebula (M17), and the photogenic Trifid Nebula (M20), all in Sagittarius, along with the Eagle Nebula (M16) in Serpens. The North counters with many large and beautiful nebulae, but none rivals what we see in the South. The expansive North America Nebula (NGC 7000) in Cygnus, the California Nebula (NGC 1499) in Perseus, and the Rosette Nebula (NGC 2237–9) in Monoceros were all missed by Messier.

For our last object in this category, we must leave the confines of the Milky Way to explore one of the greatest diffuse nebulae in the known universe, the Tarantula Nebula (NGC 2070) (South), located 180,000 light-years away near the eastern end of our neighboring galaxy, the Large Magellanic Cloud. This magnificent object is so huge (its bright inner region is 750 light-years across) that if it were placed at the same distance as the Orion Nebula, it would span 30° of the night sky and blaze two or three times brighter than Venus! In the telescope it appears as a kaleidoscope of loops, knots, and streamers emanating from a great central bar. Even though it is 10 times farther away than all the treasures described above, it rises well above the threshold of naked-eye visibility. Deep in the heart of the nebulous monster is its radiant engine, the brilliant star cluster 30 Doradus (NGC 2070).

The envelope, please. For the best overall category, the South wins by a mile. First prize must go to the Orion Nebula for its variety of colors, asymmetry, veil-like features, and the Trapezium. Because the nebula is so close to the equator, we'll split its points equally between North and South (is our northern bias showing through?). Second place goes to the Eta Carinae Nebula (South). Third also goes to the South for the Tarantula Nebula.

Score after four events: South 37.5, North 18.5.

SCORE BY CATEGORY

Class of Object	North	South
Open Clusters	8	6
Globular Clusters	0	14
Planetary Nebulae	8	6
Emission Nebulae	2.5	11.5
Galaxies	5.5	8.5
Final Score	24	46

CAST YOUR VOTE

Which hemisphere do you think has the richest treasures of deep-sky objects? Cast your vote at *Astronomy*'s website www.astronomy.com, or send your thoughts to northvssouth@astronomy.com, or write to: North vs. South, *Astronomy*, P.O. Box 1612, Waukesha, WI 53187.

Galaxies

Let us settle at the outset that the winner of the overall category must be the North. The North, which is largely clear of the obscuring clouds of the dust hugging the plane of the Milky Way, boasts the best clusters of galaxies, above all, the glorious Coma-Virgo cluster, centered on the Virgo-Coma Berenices border. Sweeping up the ghostly members of these galaxy-rich fields reveals no less than 15 Messier objects and many fainter NGC objects.

But what about individual galaxies? For best overall galaxy, the first object that springs to mind is the Andromeda Galaxy (M31) (North), the biggest and brightest spiral galaxy to grace the heavens. But for all its fame and photographic grandeur, M31 is a somewhat disappointing object in amateur scopes. It appears as little more than an elongated foggy patch swirling around a brilliant starlike nucleus.

Another notable spiral is the sprawling Pinwheel Galaxy, M33 in Triangulum (North). It is 80' in diameter and has an overall magnitude of 5.7. Despite its large size and relative proximity to Earth (2.7 million light-years), it is often overlooked because of its low surface brightness.

The South also has some noteworthy galaxies. NGC 253, the brightest spiral galaxy in the Sculptor Group, is, after M31, the most easily observed spiral in the heavens. But the most awe-inspiring of all southern galaxies is the monster elliptical galaxy NGC 5128 (also known as radio source Centaurus A), located 14 million light-years away. Even in small telescopes it appears as a bright, hazy, round spot transected by a dark dust lane. The dust lane is the remnant of a smaller galaxy gobbled up by the giant elliptical.

And the envelope, please.

But wait! We've forgotten something: the Magellanic Clouds. Though satellites of the Milky Way, they are notable galaxies in their own right. The Large Magellanic Cloud is an irregular barred spiral, comparable to the average spiral in size and luminosity. Even small telescopes reveal some of its rich treasure trove (keep in mind that using only a 20-inch telescope on the LMC is equivalent to using a 200-inch on M31). There are giant emission nebulae, including the Tarantula Nebula mentioned above. There are also some brilliant star clusters, including 30 Doradus and NGC 1910.

The Small Magellanic Cloud, located 22° from the LMC in Tucana, is circumpolar in southern skies. It is a splendid object in its own right. But frankly, it tends to be overshadowed by its more spectacular counterpart. Admittedly, there are no objects to compare with the Tarantula Nebula. But like the LMC, the SMC is resolvable into stars with modest telescopes.

First place goes to the LMC (South), second place goes to the SMC (South), and a distant tie for third is split between the Andromeda Galaxy (North) and NGC 5128 (South).

The final score: South 46, North 24.

The South wins the competition hands down. By our admittedly subjective and unscientific scoring system, its skies would appear to be twice as grand. Perhaps if we had included some of the other possible categories, or more objects in each category, the advantage would have tilted more to the North. But regardless of our score, how about holding your own contest? Draw up your own lists! Have fun!

Frequent Astronomy *contributor and author William Sheehan has developed an insatiable passion for deep-sky objects. Veteran deep-sky observer Laurence Field is a zoologist at the University of Canterbury in Christchurch, New Zealand.*

Learning the Southern Skies

ONLINE

You can earn this master's degree focusing on Australian skies.

Text and photos by David Cortner

When night came to Sydney, I was 40 hours out of Charlotte, North Carolina, without meaningful sleep. Still, astronomer Graeme White thought there was something I just had to see. His colleague Maria Hunt said she knew where to find it.

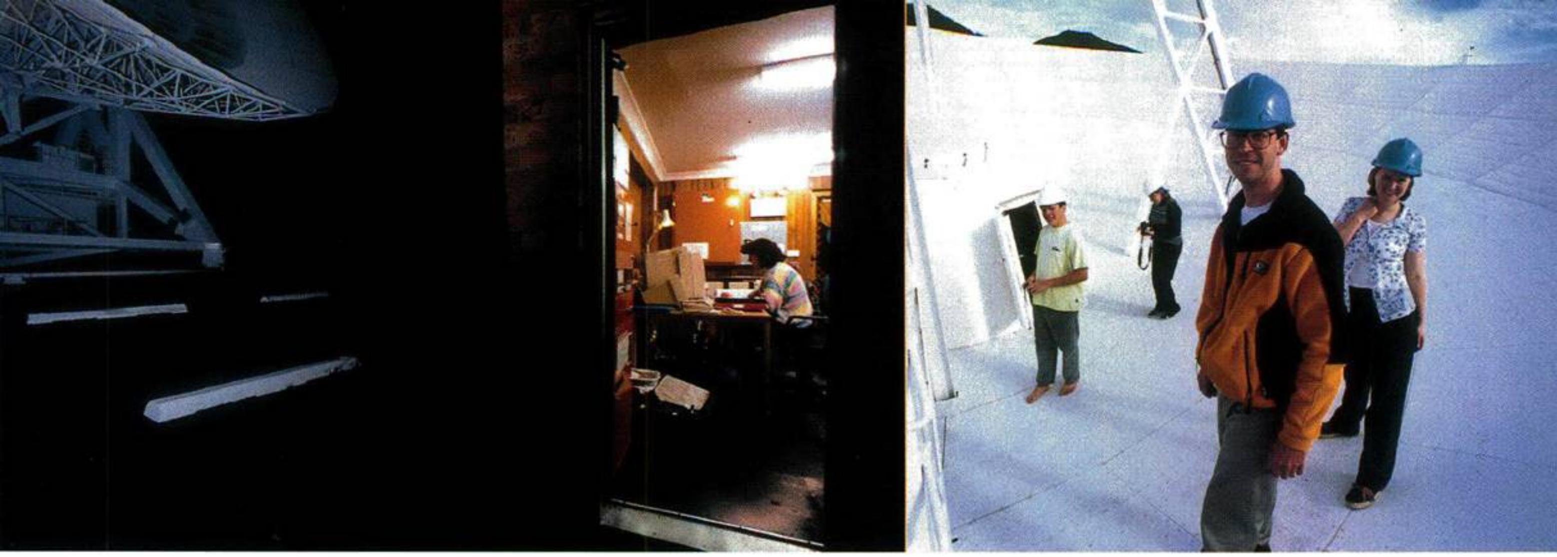
I rode with Graeme as we trailed Maria's car up the serpentine Great Western Highway into the Blue Mountains. High up the mountain face, Maria turned down a narrow path through tall trees. Graeme followed slowly, using only his Miata's parking lights. Ink-black forests and thousand-foot drop-offs notwithstanding, there was dark adaptation to consider. We caught up with Maria in a large clearing.

"How's this?" she asked.

It was, in a word, magnificent. The southern Milky Way blazed above the canopy of gum trees. After 43 years on planet Earth and 35 years of stargazing, a new firmament shone above my head.

I had come halfway around the globe to get a true view of an ambitious program that offers a master's degree in astronomy — one that you can earn through coursework

South circumpolar star trails grace the sky above Nepean Observatory.



Left to right: Maria Hunt observes with the 22-meter Moora Dish in Coonabarabran, Australia. Rob Hollow and three students take a walk in the Mopra Dish.

conducted entirely over the Internet. The first of two Internet astronomy study programs offered in Australia, this one is offered by the University of Western Sydney. The administrative details of the Astronomy Internet Master's (AIM) are best learned straight from the kangaroo's pouch by visiting the program's web pages. These, however, are the answers to the most frequently asked questions: It takes three years of part-time study to complete the master's; tuition costs $7,000; and you're technically qualified to attempt the master's program if you already hold a bachelor's degree in almost anything.

Maria, who has been instrumental in establishing AIM, has to leave us and drive back to town. I need some time to sort out the alien sky. Graeme, expert astrometrist, investigator on Hipparcos and the Hubble Space Telescope, professor of astronomy at the University of Western Sydney — and longtime amateur astronomer — popped open the boot of his sports car and extracted an Edmund Astroscan.

"David, look at this," he said for the first of many times. "Here's Alpha Centauri. What a terrific double." We visited the Jewel Box, Eta Carinae, Omega Centauri, and fields crowded with open clusters. The blue-white star clouds of the southern Milky Way arched over the clearing and down behind still trees. "Here's how to find the celestial pole. . ." Graeme said.

The next day, Graeme introduced me to the faculty and staff of the Nepean Centre for Astronomy. White and his crew convinced the University of Western Sydney that they could offer a solid master's degree in classes conducted over the Internet. His next task is to convince the world. He intends AIM to be as respectable as any degree earned by attending classes in person.

Graduate student (and pathfinder) Maria Hunt began AIM in 1996. When she became manager of the Nepean Observatory, degreed faculty took over. At lunch in the quad, Maria asked what Graeme and I had seen after she left. Omega Centauri in the zenith, I gushed, swarms of brilliant stars, nebulae brighter than Orion's. "The usual stuff," Graeme laconically summarized.

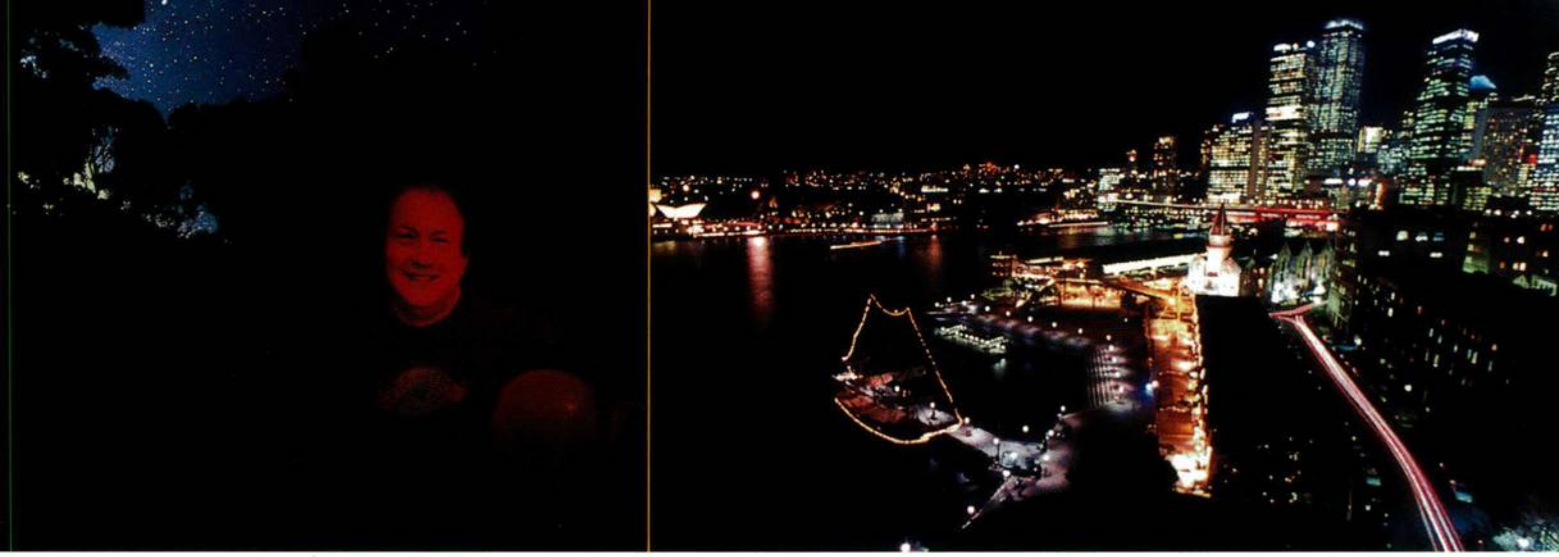
Lecturer Alex Hons (a lecturer in Australia is equivalent to an associate professor in America) inherited the AIM program from Maria. On a commuter ferry to Manly, Alex said that by offering a graduate degree only, the program was freed from diverse core requirements and the vital chaos of students discovering what college is all about while they also discovered who they themselves are. Through AIM, the University of Western Sydney offers concentrated doses of what mature students want. Not by accident, knowledgeable amateur astronomers make ideal candidates.

AIM students meet instructor Ross Cutts early. His introductory courses insure that all online students have enough astronomical savvy to survive later, more advanced offerings. Ross marvels at the dedication his nontraditional students bring to their studies. Some have completed observing assignments in 40-below-zero weather. One woman finished assignments in the delivery room.

NONTRADITIONAL STUDENTS

My home in Australia was the spare bedroom in Graeme's apartment. From the moment I arrived, I knew Graeme White was a high-energy astronomer. I do not mean that he studies cosmic rays. On a single one-hour train ride into Sydney, we talked about an upcoming conference on astronomical education, the promise of co-adding short exposure astrophotos, a naturalists' tour to the outback for a solar eclipse in 2002, supernova sleuth Bob Evans's plans to use the Centre's CCD remotely when moonlight frustrates his visual searches, and setting up an exchange program between the University of Western Sydney and my own university.

Graeme showed me Sydney Observatory. He pointed to a footing of the Harbour Bridge and said it was where William Dawes had built his observatory in 1788. Dawes arrived with the First Fleet, aboard the Sirius. Brisbane, an early governor, was also an astronomer. But Australia's astronomical roots reach even deeper than the famous prison ships: The voyage on which Captain Cook claimed Australia for the Crown began as an expedition to time a transit of Venus.



Left to right: Graeme White guides the view of the southern skies. The fabulous lights of downtown Sydney lure the author, but can't compete with dark-sky locations.

Over steaks in a downtown tavern, Graeme recounted his epiphany during a 1993 meeting with American astronomer Jay Pasachoff at Williams College. That meeting pushed Graeme into hustling for science education in addition to hustling for science.

After dinner we walked to the Sydney Opera House. We circumnavigated it inside and out. We talked about a poster by Akira Fujii on Graeme's living-room wall showing the Milky Way from Crux to Carina. ("Imagine how many dissertations are in that picture.") I asked about a comet photo on the door to his study. As an amateur, Graeme used binoculars to discover Comet White-Ortiz-Bolelli (1970f). The souvenir of his amateur days led us to the unlikely beginnings of his professional career. They, in turn, explained much about the Astronomy Internet Master's.

As a youth, Graeme was not admitted to a university. He was sent to technical school instead. Working at a job far from his scientific calling, his enthusiasm for astronomy waxed, waned, waxed again. He became a serious amateur. He appealed to the University of Wollongong and was granted special dispensation to attempt their program. Graeme had enough worldly experience to know a lifeline when he was thrown one. He seized it and never looked back. His rocky start convinced him the field was missing talent because similar lifelines were seldom offered to people who might become motivated, nontraditional students.

AIM is Graeme's way of throwing lifelines around the world. Like Alex, Graeme is fascinated to see who applies for AIM and why. Even more than Alex, Graeme is keenly interested in what people do with the opportunities it presents.

No one has yet graduated from the AIM program — it's still a new phenomenon. The first AIM graduates will take their degrees into the world sometime in the year 2000. For some, of course, the degree will be merely ego-boosting window-dressing for their résumés. Some AIM students will use their new degrees to help land ground-floor jobs in the sciences. They may become planetarium interns, for example, or observatory night-assistants. Others will use the degree to start teaching careers at community colleges. For some students, the AIM will be a career- or life-changing credential — just as advanced degrees change the lives of students who seek them more traditionally.

SIDING SPRING OBSERVATORY

I joined Maria Hunt and her two youngest children for a few days and nights at the 22-meter radio telescope at Mopra near Siding Spring Observatory and Warrumbungle National Park. I wanted to see astronomers doing astronomy, dark skies, and kangaroos.

The long drive to tiny Coonabarabran ("The Astronomy Center of Australia") passes through remote, beautiful country. At twilight, my nose to the window, I watched unfamiliar stars come out. I was amazed to see the dark Coalsack before I saw the Milky Way.

With Tony and Alicia asleep in the backseat, Maria described how she came to astronomy. Working as a registered nurse, years after college, she realized she'd never given up her grade-school enthusiasm for science. Maria quit her job and returned to University at Western Sydney where she found an ideal, if sometimes manic, mentor in Graeme White. On the verge of her doctorate, she spends a lot of time piloting radio telescopes and observing the molecular clouds of the Milky Way. Maria was planning a whirlwind tour of the United States in search of contacts, ideas, and insight for improving astronomical education. Her stateside schedule dovetailed with an observing run in Chile. It was a long way from IV bags and bedpans.

On our final trip into Sydney, I pressed Graeme for the nth time about AIM's lack of math prerequisites. Australians call mathematics "maths." No matter what you call it, math is the traditional Waterloo for would-be astronomers. This time Graeme was primed.

"Look, Sunshine," he said, "astronomy isn't physics and it's a mistake to think it is. It takes a lot of maths to do physics, but you can do a lot of astronomy without a lot of maths. We have a graduate student, not an AIM student, who's doing his doctoral work on the Dunlop Catalog. The only maths he really needs is the ability to add a column of numbers and divide by 24. He's doing real astronomy and he'll be a fine astronomer. If a student picks a subject that requires a lot of maths, he'll get it. It's like everything else in graduate school: You'll learn what you need to do your research or you simply won't get the credit."

I scribbled to get this down verbatim. Graeme wanted to continue. I waved him off until I finished my notes. I read them back. His pent-up enthusiasm waxed.

Graeme emphasized what the AIM is not: It is not a research degree. The program was not designed to be a direct stepping stone into a doctoral program or into astronomical research. It's designed to give students opportunities in the sciences that they wouldn't otherwise have. "An AIM will help get you the interview," he said, "After that, as with any degree, it's up to you."

"AIM is fully accredited in Australia, but no one knows how it will be received elsewhere," he said. "The real point is that people everywhere with a lot of different backgrounds can use it to open doors."

In the beginning, an Astronomy Internet Master's will be an unusual credential whose novelty will spark interest. Graeme is determined to see it command respect. Graeme offered me a "satellite view" of distance education Down Under. Australia has world-class astronomical facilities and universities full of talented scientists. Facilities built to study the southern half of the universe could serve legions of graduate students. And so where are the students? Where could they come from?

All of Australia has fewer than 20 million people, about as many as southern California. The island continent is a long, expensive commute from everywhere. To find the students to fill its educational capacity, to support its educational infrastructure, Australia needs the Internet and distance education. Programs such as AIM and Swinburne University of Technology's "Astronomy Online" are natural responses to Australia's sparse population, isolation, and unique astronomical opportunities.

I spent my last evening in Australia beside Nepean Observatory. Car lights traced the now-familiar Great Western Highway up and over the Blue Mountains. Venus blazed in a deepening sky. I asked senior lecturer and astronomer Paul Jones why distance education at the University of Western Sydney, Nepean, was such a good idea.

"Well," he said, a mischievous smile coming out on his face the way the Southern Cross was coming out in the sky, "the campus is infested with brown snakes." ■

David Cortner is a freelance writer/photographer and avid amateur astronomer who lives in North Carolina.

HOW ONE WRITER CRASHED AN ONLINE COURSE

When I first heard about the Astronomy Internet Master's (AIM) program, I thought it was too good to be true. Offered through the Nepean Centre for Astronomy at the University of Western Sydney, this accredited graduate-level astronomy degree can be earned entirely over the Internet, even if you don't have a math or physics background. Jim Beaber, Astronomy Resource Specialist at the Jefferson County Colorado School District Planetarium, had just enrolled and sent me glowing reports.

AIM uses a creative combination of online lectures, e-mail tests, and interactive projects, all delivered via a cyber classroom called TopClass. I had the opportunity to sit in on a first semester course in fundamentals of astronomy and was pleased at the ease of navigating an Internet classroom.

The students in my class lived worldwide. Some were local Australians, others lived in the United States, Europe, and Asia. A few, like Beaber, were already involved in astronomy, but most came to the program as seasoned amateur astronomers.

Introductory classes are balanced between lectures and practical applications. For example, in Ross Cutts's fundamentals course, one lecture on the solar system is accompanied by observing assignments. With fundamentals and two other introductory courses behind them, students move on to study modern observing tools and techniques.

Then they begin to hone their research and collaboration skills through an in-depth project in the history of astronomy. During this course, class members form study groups to research one of several topics posted on the Internet, discuss their topics online, and then write a group report.

Students often do research on their local astronomical facilities. They might, for example, learn the history and inner workings of an observatory or research center through first-hand interviews.

In later semesters, students learn to navigate the current scientific literature through demanding projects in contemporary astronomical research and instrumentation. These projects prepare students for their ultimate semester in which they produce a professional-quality paper, one ready for publication in a refereed journal.

Throughout the AIM program, students's chosen projects are as varied as the class members. They range from Jim Beaber's "History of Human Understanding of the Milky Way" to another student's "Comets of the 16th through 18th Century." Others have studied subjects such as the cosmologies of Aboriginal peoples and the effects of astronomical discovery on culture at large.

Nepean Observatory's 24-inch Cassegrain telescope — the largest on-campus scope in Australia — will soon be integrated into the AIM program. When it comes online, students interested in observing projects will conduct astrometric, photometric, and other research through remote-control CCD imaging of the southern sky.

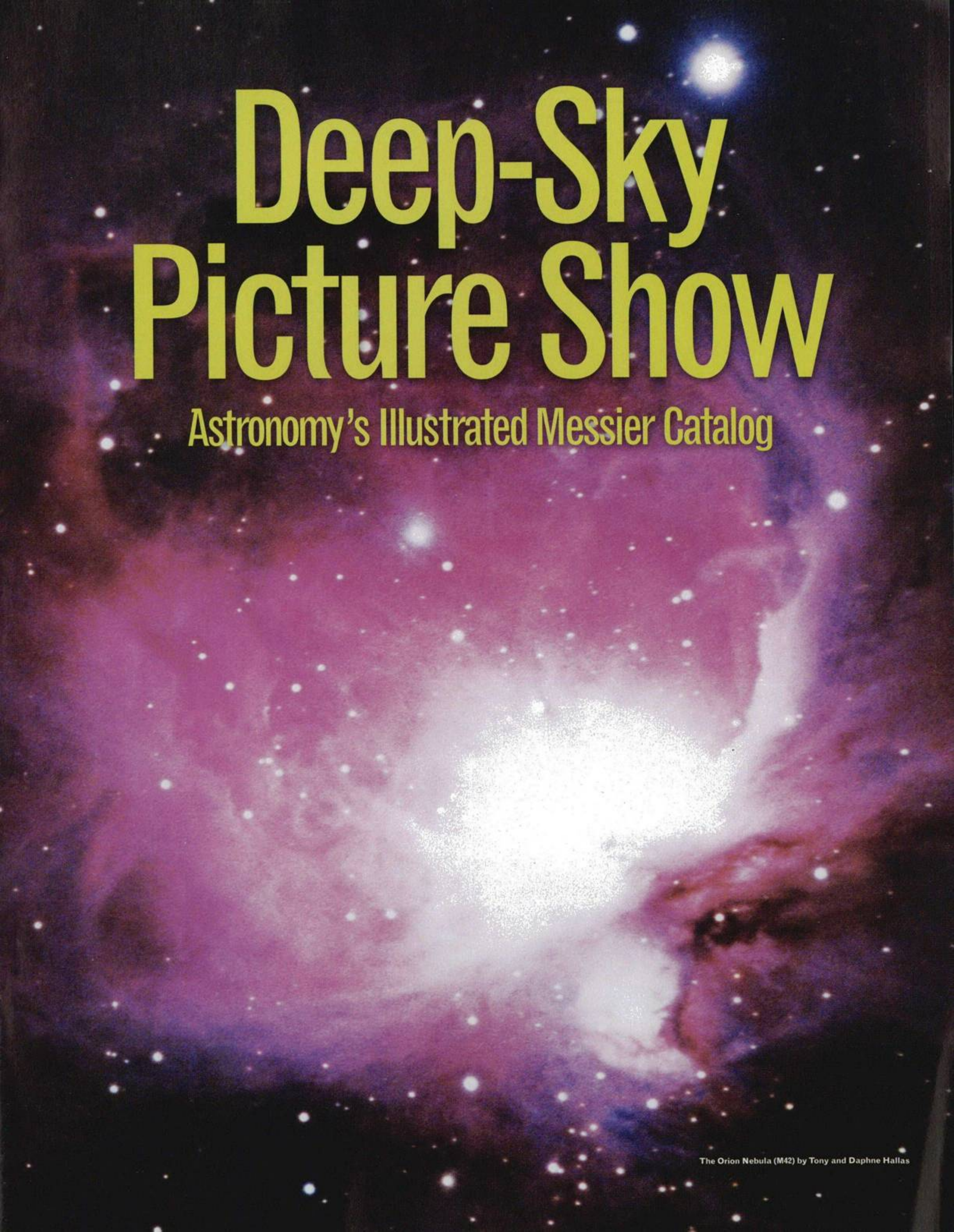
"This program will allow me to take courses that I could only get if I dropped out of teaching and went to school full-time," says Beaber.

A master's of astronomy degree requires a student to successfully complete 120 Student Load Factors (SLFs) over a period of six semesters. Most classes count for 10 or 20 SLFs. Lesser credentials than the master's are offered at "exit points" beginning after the third semester. For details, visit the AIM front office at http://www.nepean.uws.edu.au/astronomy/Aim.info.html.

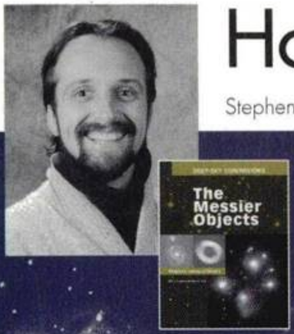
— Nancy Hendrickson

Deep-Sky Picture Show

Astronomy's Illustrated Messier Catalog



The Orion Nebula (M42) by Tony and Daphne Hallas



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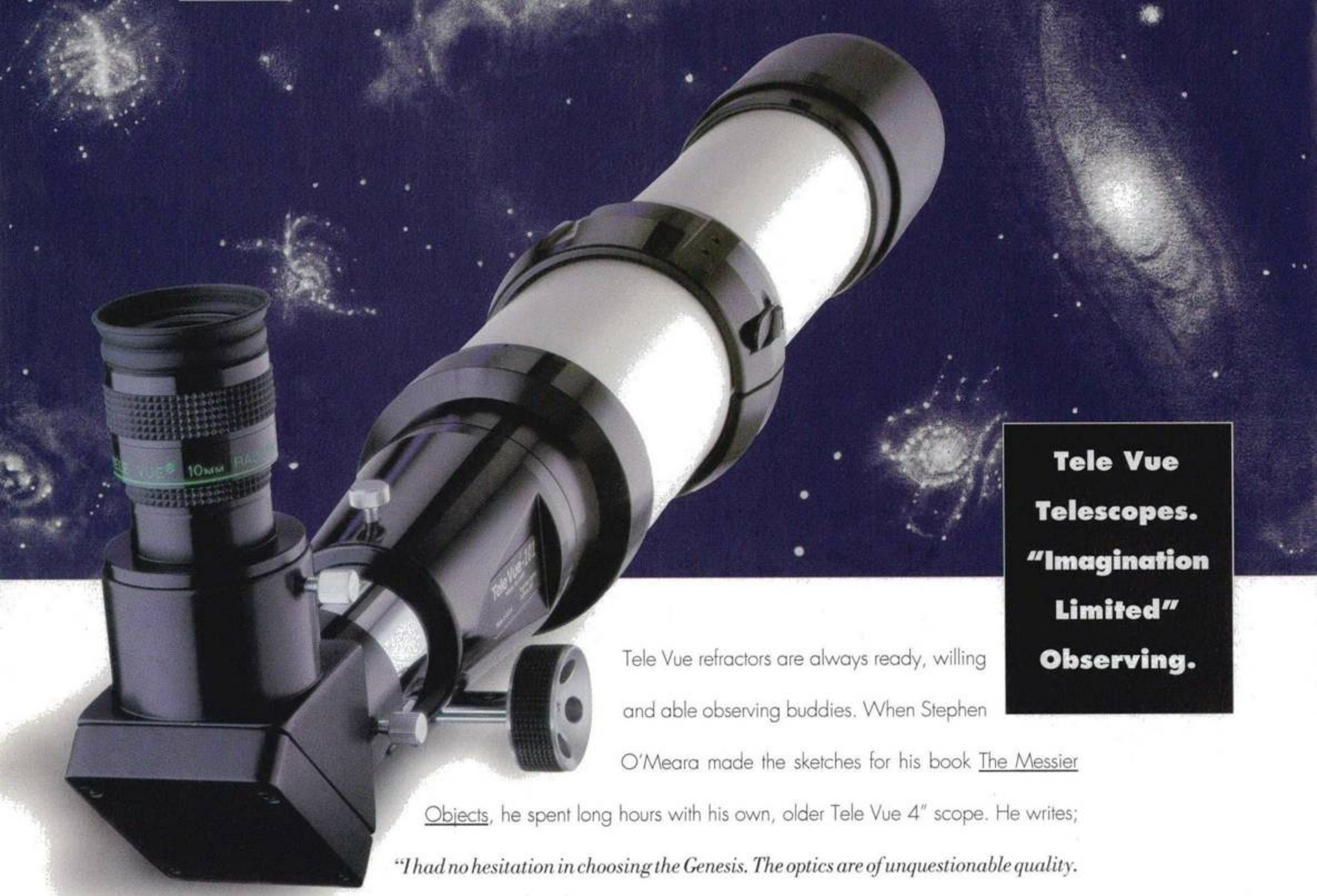

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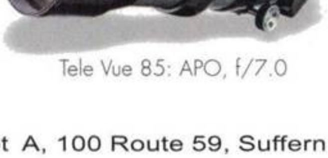

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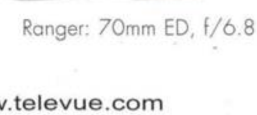

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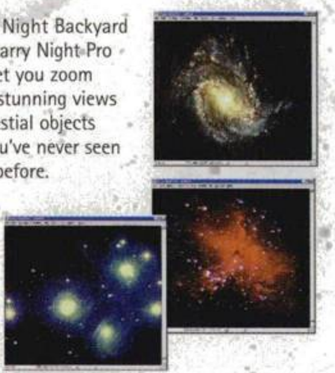

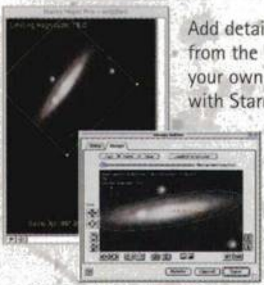

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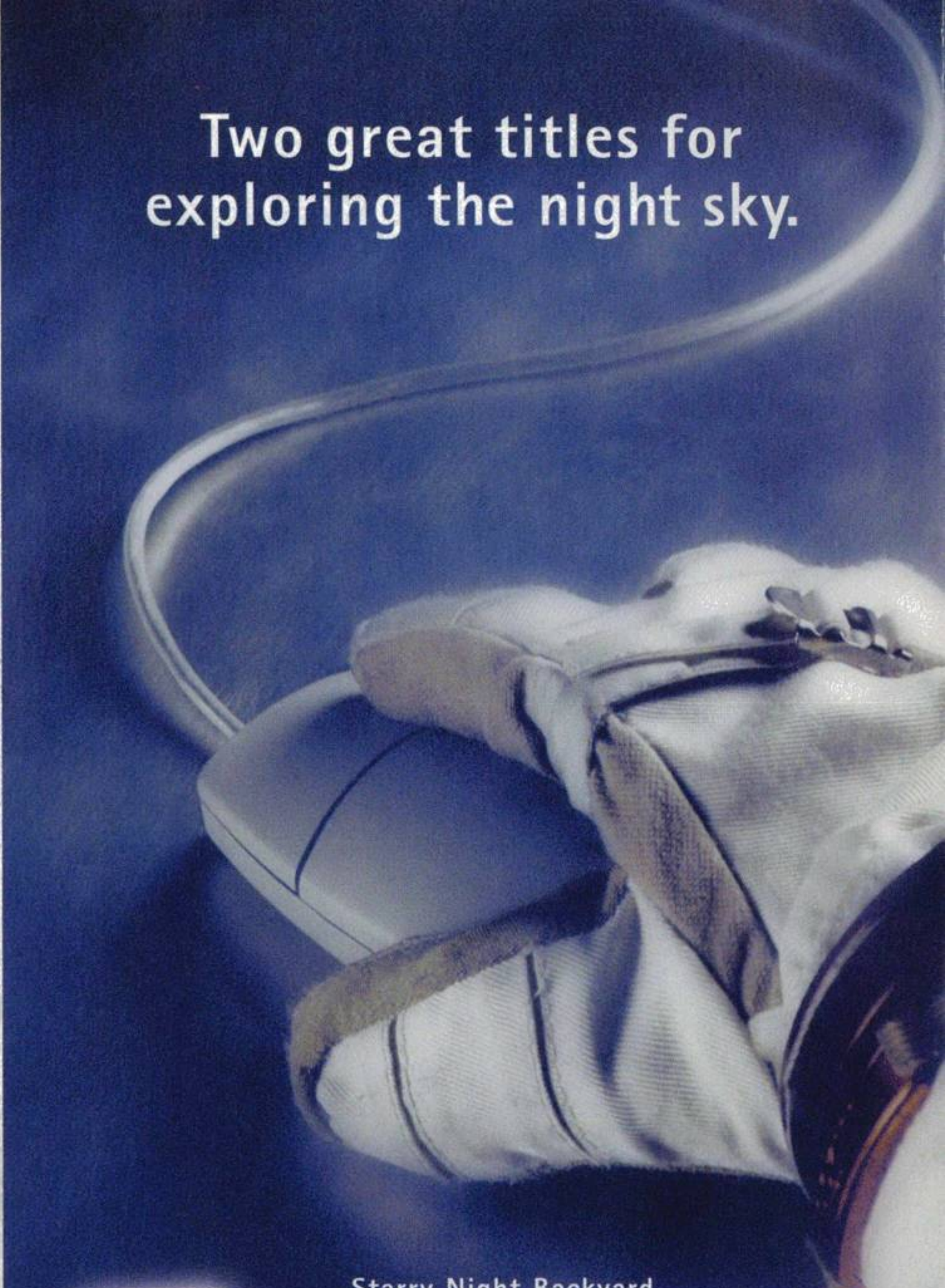

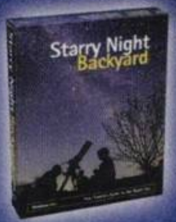

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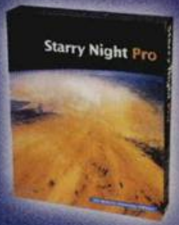

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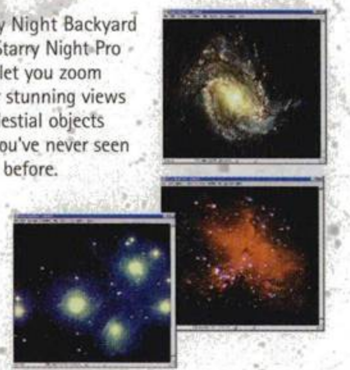

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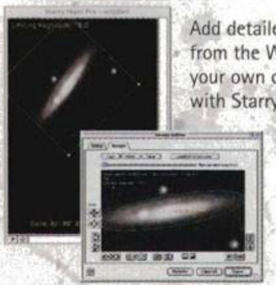

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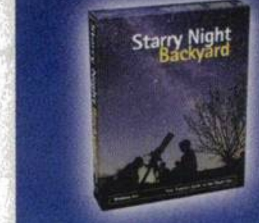

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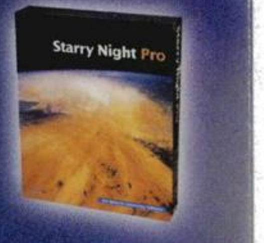

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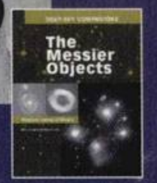

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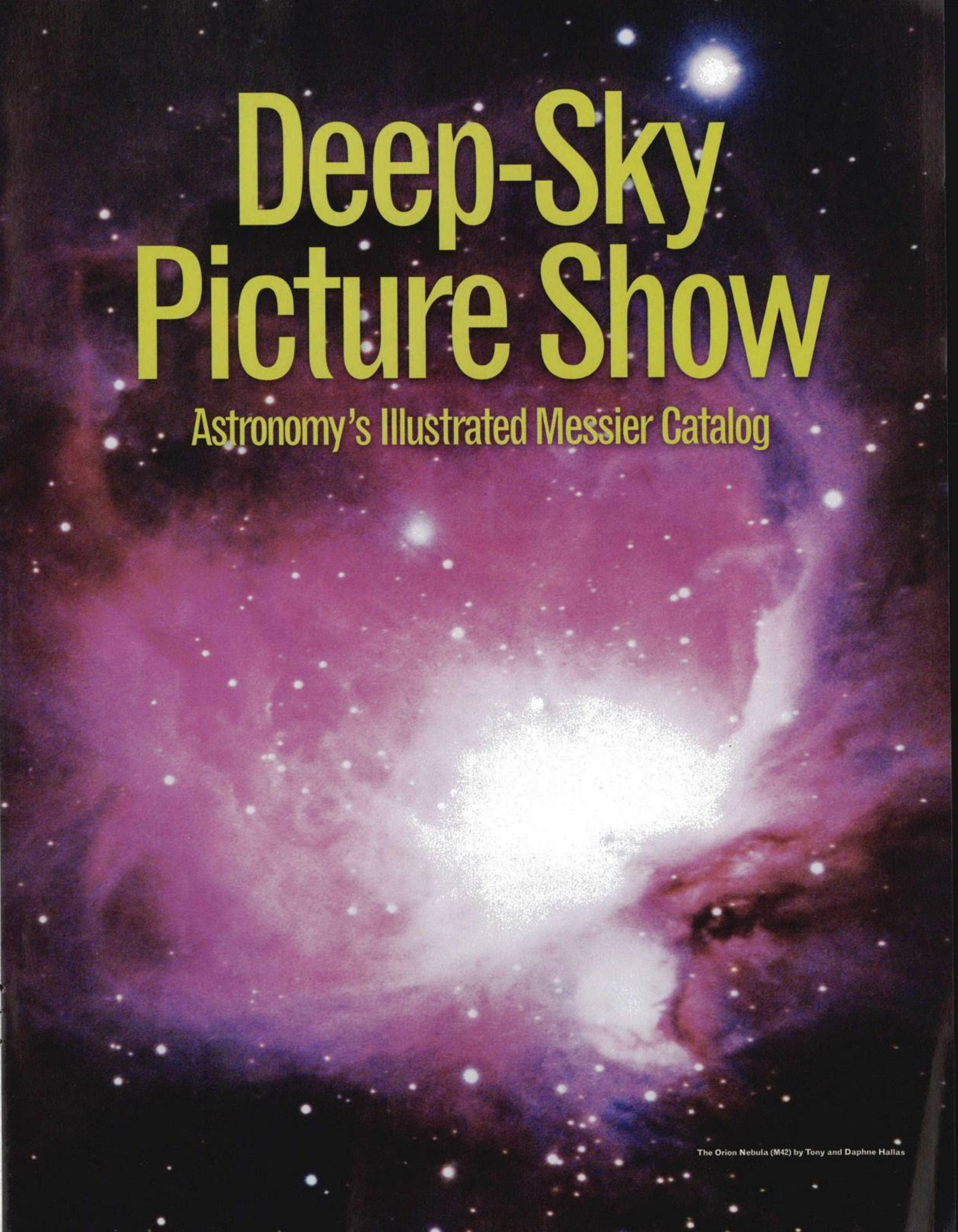
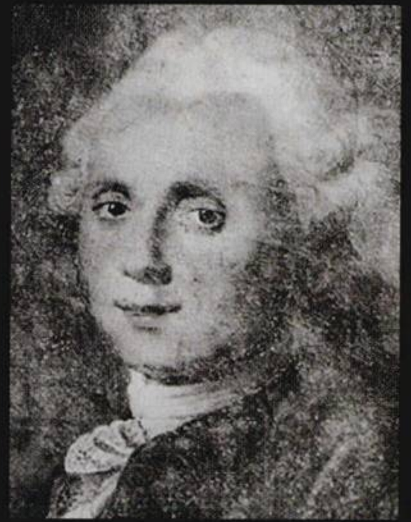


The Orion Nebula (M42) by Tony and Daphne Hallas

The Messier Catalog at a Glance



In the middle 18th century, astronomy was exploding with discovery. Telescopes turned to unexplored portions of sky revealed dozens of previously unseen objects. The task of the day was to catalog the sky's objects so that astronomers would be able to routinely find and study them. Many of the fuzzy, glowing objects termed "nebulae" seemed fixed in position, but others — comets — moved relative to the stars.

The French astronomer Charles Messier (right, 1730–1817) set about cataloging the fixed nebulae so they would not be confused with comets, his real passion. His initial catalog of 45 objects was published in 1774. Messier added to the list, bringing the total to 68 by 1780; his protégé Pierre Méchain ballooned the catalog to 103 objects by 1787, and later astronomers added seven more, believing that Messier had observed them. So the list, despite idiosyncrasies and replacements, stands at as many as 110 objects.

Messier's catalog of nebulae, which we now know to be nebulae, star clusters, and galaxies, came to be the standard list of wonderful sky targets for amateur astronomers. Many of the brightest, most impressive deep-sky objects visible to Northern Hemisphere viewers belong to it. It thus serves as a "greatest hits" compilation of the deep sky.

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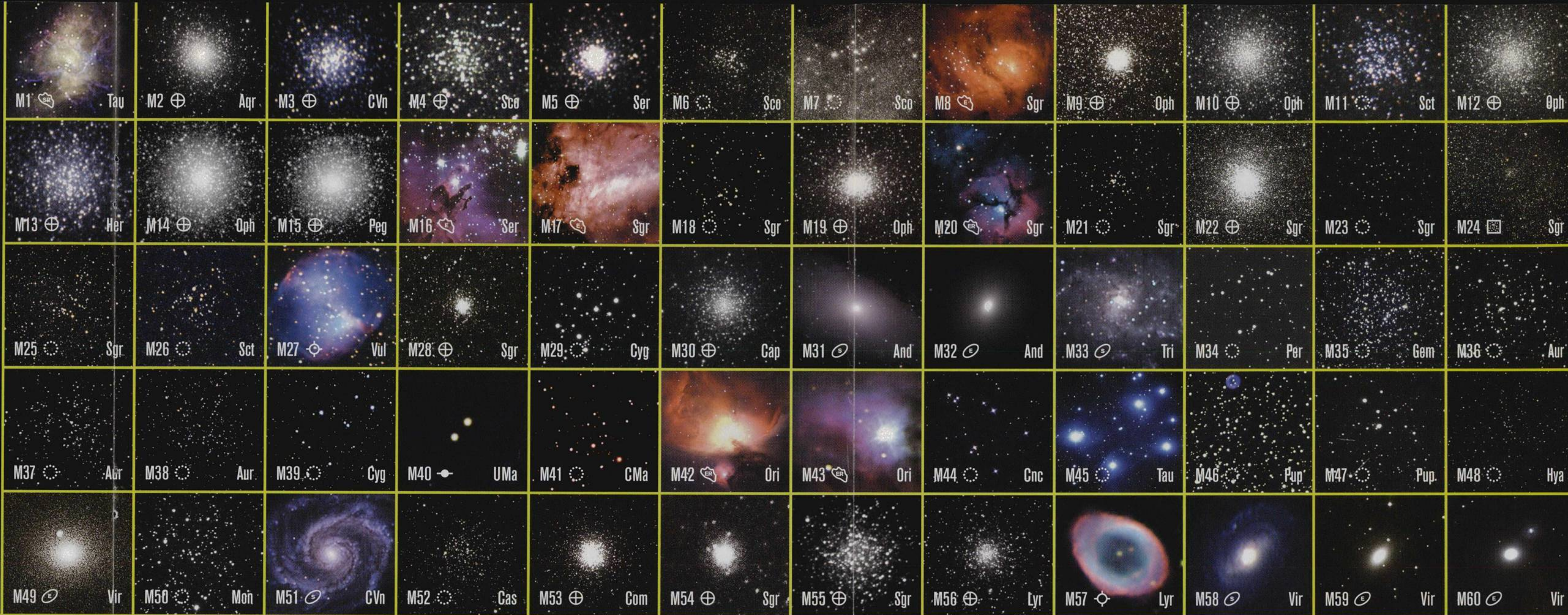
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M3 CVn
M4 Sco
M5 Ser
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M7 Sco
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M11 Sct
M12 Oph
M13 Her
M14 Oph
M15 Peg
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M26 Sct
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M28 Sgr
M29 Cyg
M30 Cap
M31 And
M32 And
M33 Tri
M34 Per
M35 Gem
M36 Aur
M37 Aur
M38 Aur
M39 Cyg
M40 UMa
M41 CMa
M42 Ori
M43 Ori
M44 Cnc
M45 Tau
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M47 Pup
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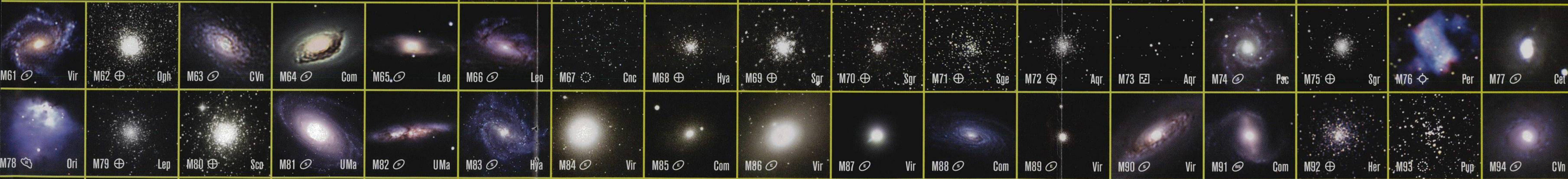
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M80 Sco
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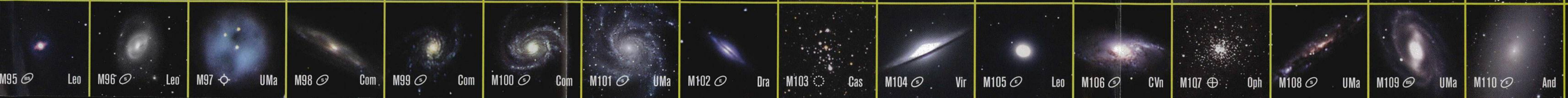
M95 Leo
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M98 Com
M99 Com
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M102 Dra
M103 Cas
M104 Vir
M105 Leo
M106 CVn
M107 Oph
M108 UMa
M109 UMa
M110 And

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12mm 1.25"	.228	16mm 2"/1.25"	.310
14mm 1.25"	.228	**NAGLER Type 4 (82°)**	
18mm 1.25"	.228	12mm 2"/1.25"	.340
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sky Show

june

Mercury makes a bright appearance, and an asteroid appears to the naked eye.

by Martin Ratcliffe and Alister Ling

Catch Mercury at its peak while there is still time. The first weeks of June see the fleet-footed planet attempting a high jump from the horizon. But it only clears the bar marked by the dimmer Delta (δ) Geminorum before it quickly sinks back into obscurity. Mercury is surprisingly easy to locate when you know how. Just note where the sun sets, extend your arm in that direction and about one fist-width up is where Mercury will be in 50 minutes (page 81). By mid-June, Mercury fades by more than a factor of two, so you should notice it getting harder to see in the second week.

The arena of asteroids and comets resides farther out in the solar system. Talk of a naked-eye comet piques everyone's astronomical interests, and it's been three years since Hale-Bopp graced our skies. The new comet, LINEAR (c/1999 S4), won't be as fantastic, but we're still hoping for an enjoyable show (page 83). By the end of this month, there's a good chance that it will reach 7th magnitude, approaching naked-eye visibility. Catch a glimpse as it rises to stardom. Plan on rising in the wee hours to spy this dirty snowball, discovered by MIT's Lincoln Near Earth Asteroid Research project and their robotic telescope at White Sands, New Mexico.

The globular cluster M92 has a majestic presence through an eyepiece (page 79). Jack Newton

A great opportunity for astrophotographers will be June 30 to July 1, when the comet lies 1.2° (just over two moonwidths) from the splashy star cluster M34. This is the same cluster that showed up in many images of Comet Hale-Bopp. Brand-new comets are notoriously unpredictable, however, and often fainter than initially expected. Comets making their first journey into the inner solar system have a thin layer of carbon dioxide that quickly burns. They start brighter than an otherwise identical comet and give the false impression of being bigger. So LINEAR's brilliance may be overestimated, but we can hope for a surprise.

The summer solstice in June gives us our shortest nights of the year. But it may make the wait for midnight seem shorter, when the brightest asteroid this year, 4 Vesta, is at its best (page 83). Vesta reaches 6th magnitude, within reach of the naked eye from a dark site. It makes for a perfect challenge during star parties or camping trips.

City dwellers can follow Vesta in binoculars. This space rock is pretty big, some 340 miles (540 km) across. With a 12- to 16-inch telescope and great seeing, you should be able to see Vesta's disk, a little less than half the apparent size of Jupiter's moons.

Jupiter and Saturn return triumphantly to morning skies as July approaches (page 80). It's well worth getting up just after 4 A.M. to witness their closest naked-eye pairing since 1980. The next one will be in 2020. Add the earthlit crescent moon to the scene on the 28th and 29th and you have a great photographic opportunity.

Two meteor showers give observers a chance to catch a falling star all month. Walter Pacholka

June 2000

1 The moon passes 4° south of Jupiter, 1 A.M. EDT
Pluto is at opposition, 2 P.M. EDT (page 81)

2 New moon is at 8:14 A.M. EDT

3 The moon is at perigee (233,128 miles from Earth), 9:19 A.M. EDT
The moon passes 4° south of Mercury, midnight EDT

8 First quarter moon is at 11:29 P.M. EDT

9 Mercury is at greatest eastern elongation (24°), 9 A.M. EDT (page 81)

11 Venus is in superior conjunction, 7 A.M. EDT

13 Asteroid Parthenope is at opposition, 4 P.M. EDT

16 Full moon is at 6:27 P.M. EDT

18 The moon is at apogee (252,346 miles from Earth), 8:58 A.M. EDT

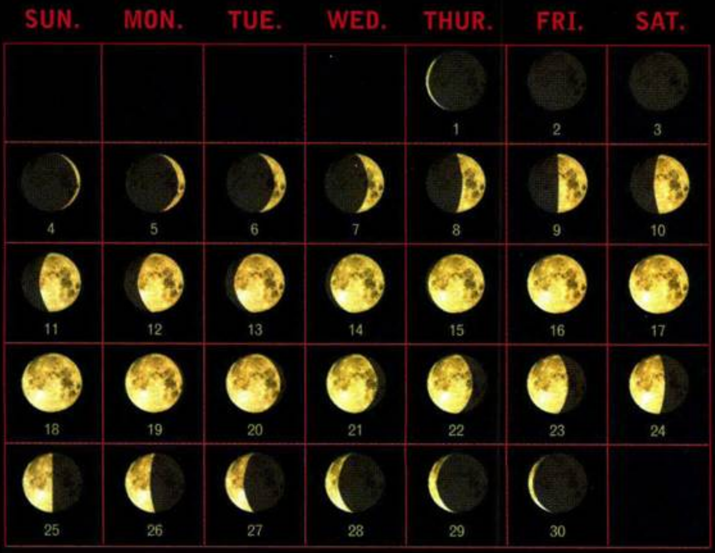
19 The moon passes 0.04° south of Vesta, 4 P.M. EDT

20 The moon passes 1.3° south of Neptune, 3 A.M. EDT
Summer solstice is at 9:48 P.M. EDT

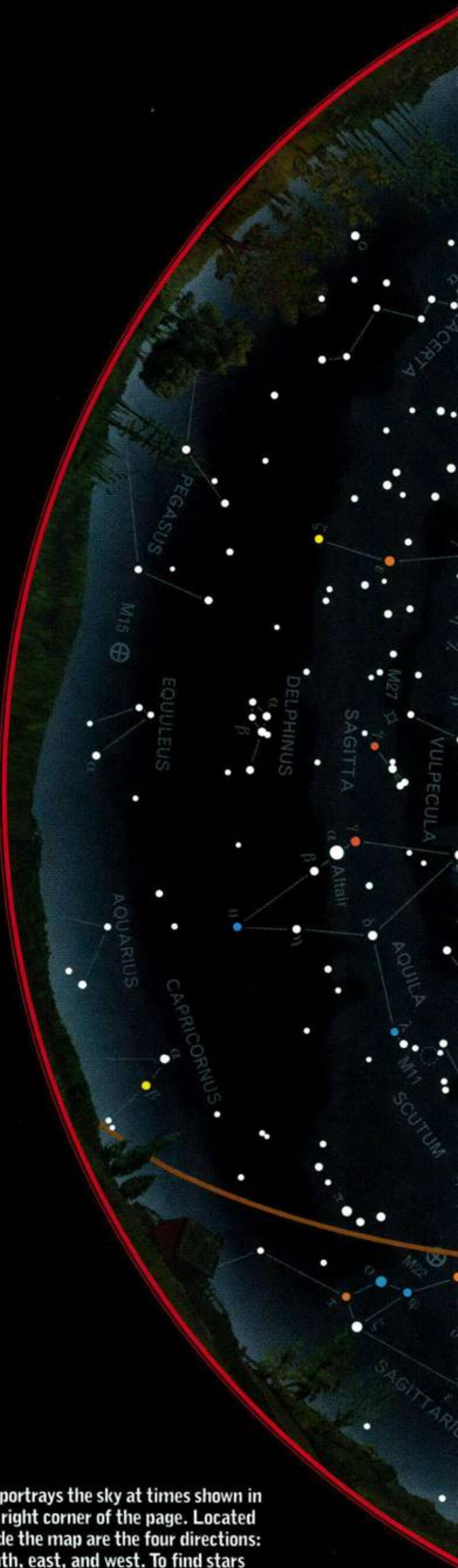
21 The moon passes 1.6° south of Uranus, 8 A.M. EDT

24 Last quarter moon is at 9:00 P.M. EDT

28 The moon passes 3° south of Saturn, 4 P.M. EDT (page 81)
The moon passes 4° south of Jupiter, 9 P.M. EDT (page 81)



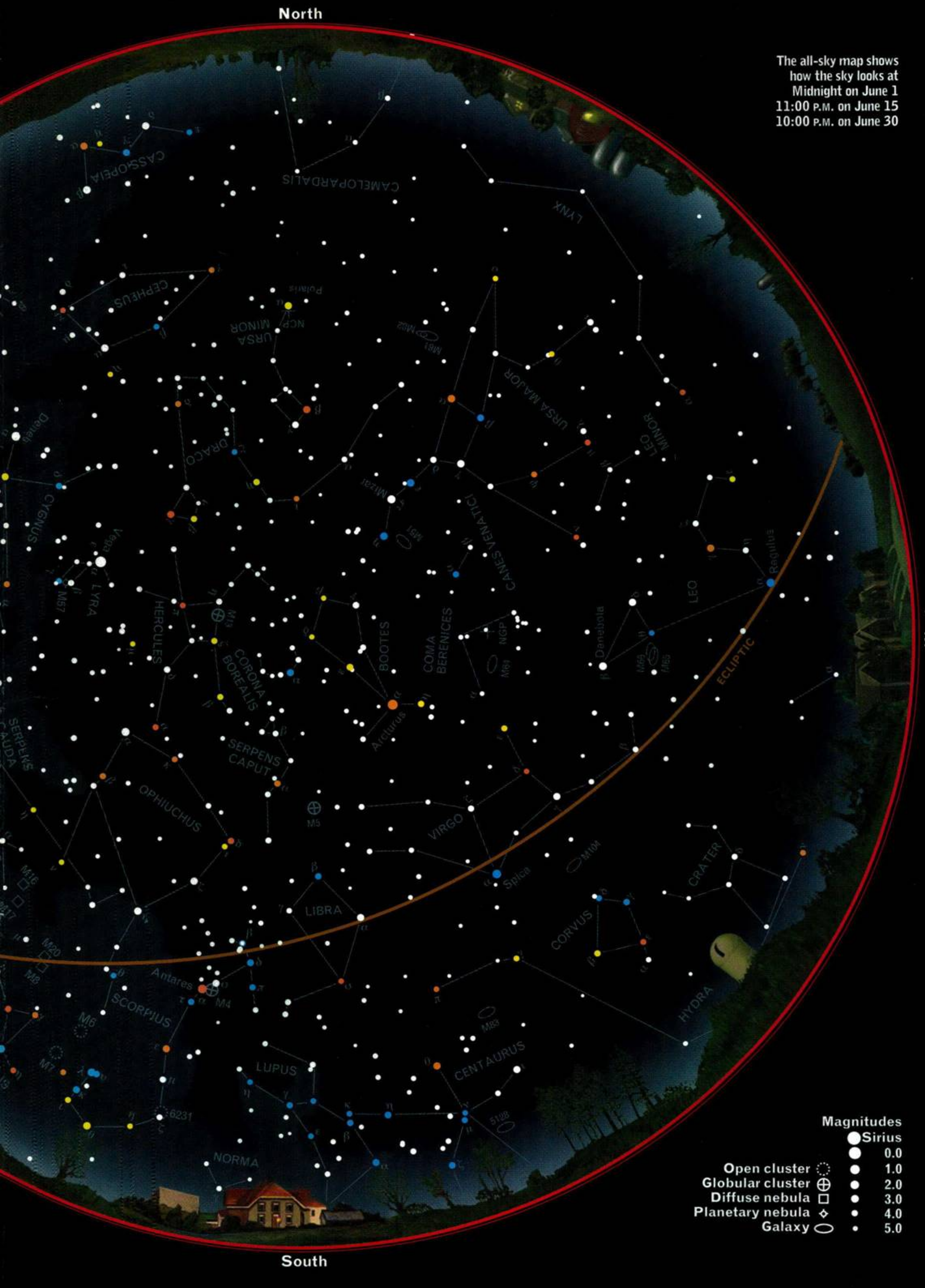
SUN.	MON.	TUE.	WED.	THUR.	FRI.	SAT.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	



East

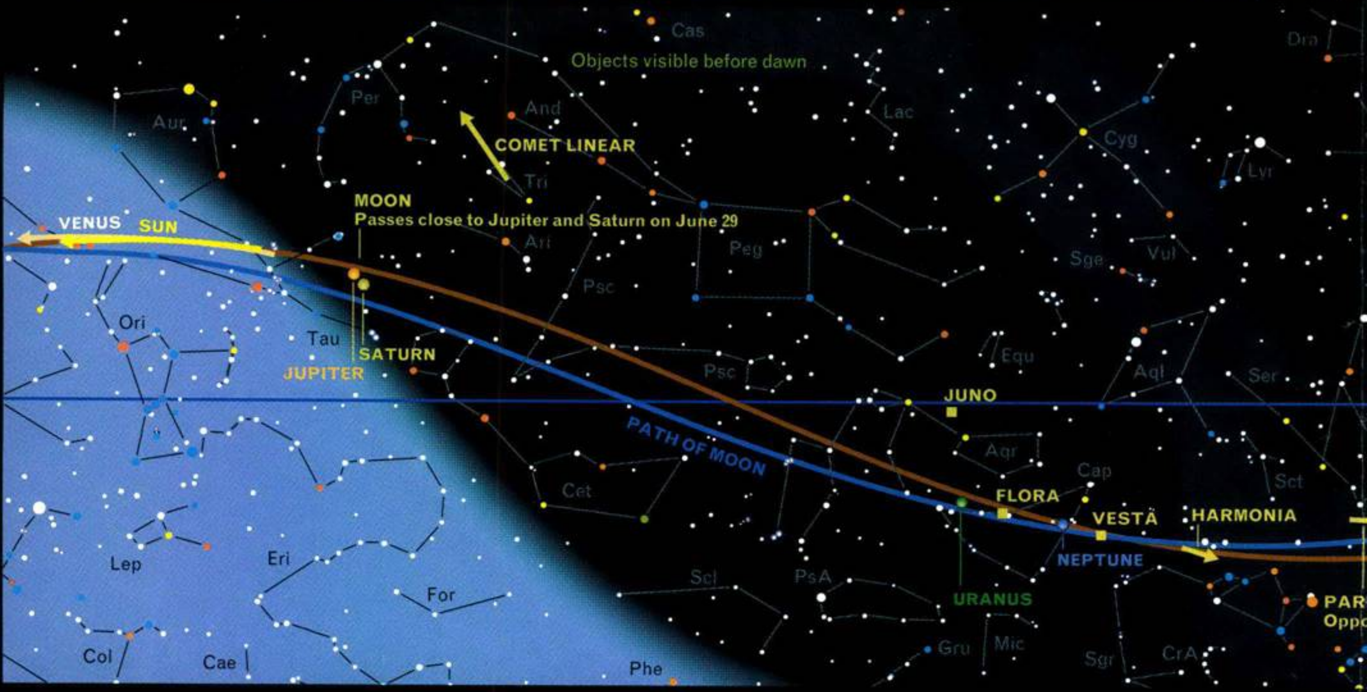
This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, *hold the map overhead* and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at
Midnight on June 1
11:00 P.M. on June 15
10:00 P.M. on June 30


North
South
West
CASSIOPEIA
CAMELOPARDALIS
LYNX
CEPHEUS
Polaris
NCP
URSA MINOR
M81
M82
URSA MAJOR
LEO MINOR
DRACO
Deneb
CYGNUS
Mizar
M51
CANES VENATICI
Vega
LYRA
M57
HERCULES
M13
BOOTES
COMA BERENICES
NGP
M64
LEO
Regulus
Denebola
M65
M66
ECLIPTIC
CORONA BOREALIS
Arcturus
SERPENS CAUDA
SERPENS CAPUT
OPHIUCHUS
M5
VIRGO
M104
CRATER
Spica
M16
M17
LIBRA
CORVUS
M20
M8
Antares
M4
SCORPIUS
M6
M7
HYDRA
M83
CENTAURUS
LUPUS
6231
5128
NORMA
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

Path of the Planets

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objec


Cas
Dra
Objects visible before dawn
Per
And
Aur
Lac
Cyg
Lyr
COMET LINEAR
Tri
MOON
Passes close to Jupiter and Saturn on June 29
VENUS
SUN
Ari
Peg
Sge
Vul
Psc
Ori
Tau
SATURN
JUPITER
Equ
Psc
Aql
Ser
JUNO
PATH OF MOON
Aqr
Cap
Cet
FLORA
Sct
VESTA
HARMONIA
NEPTUNE
Lep
Eri
Scl
PsA
URANUS
For
PAR
Oppo
Col
Cae
Phe
Gru
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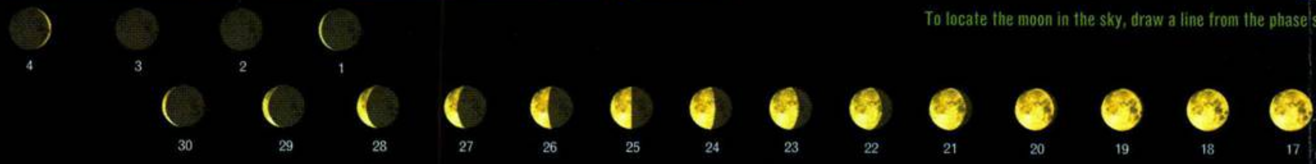
Sgr
CrA

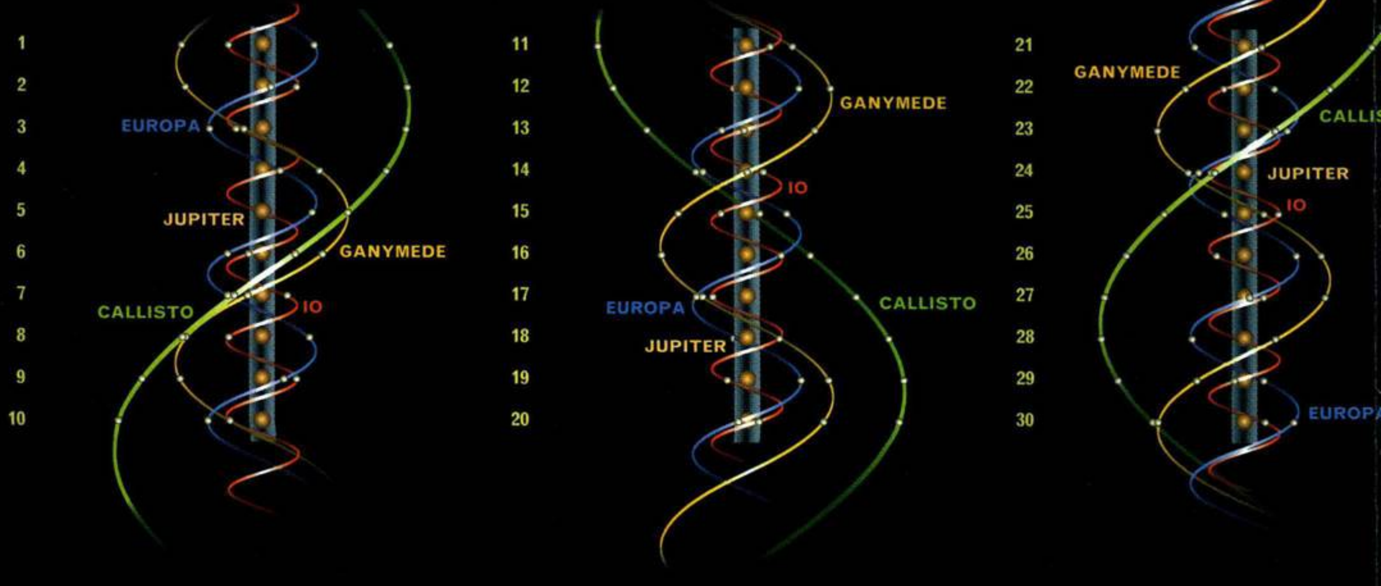

4
3
2
1
30
29
28
27
26
25
24
23
22
21
20
19
18
17

To locate the moon in the sky, draw a line from the phase s

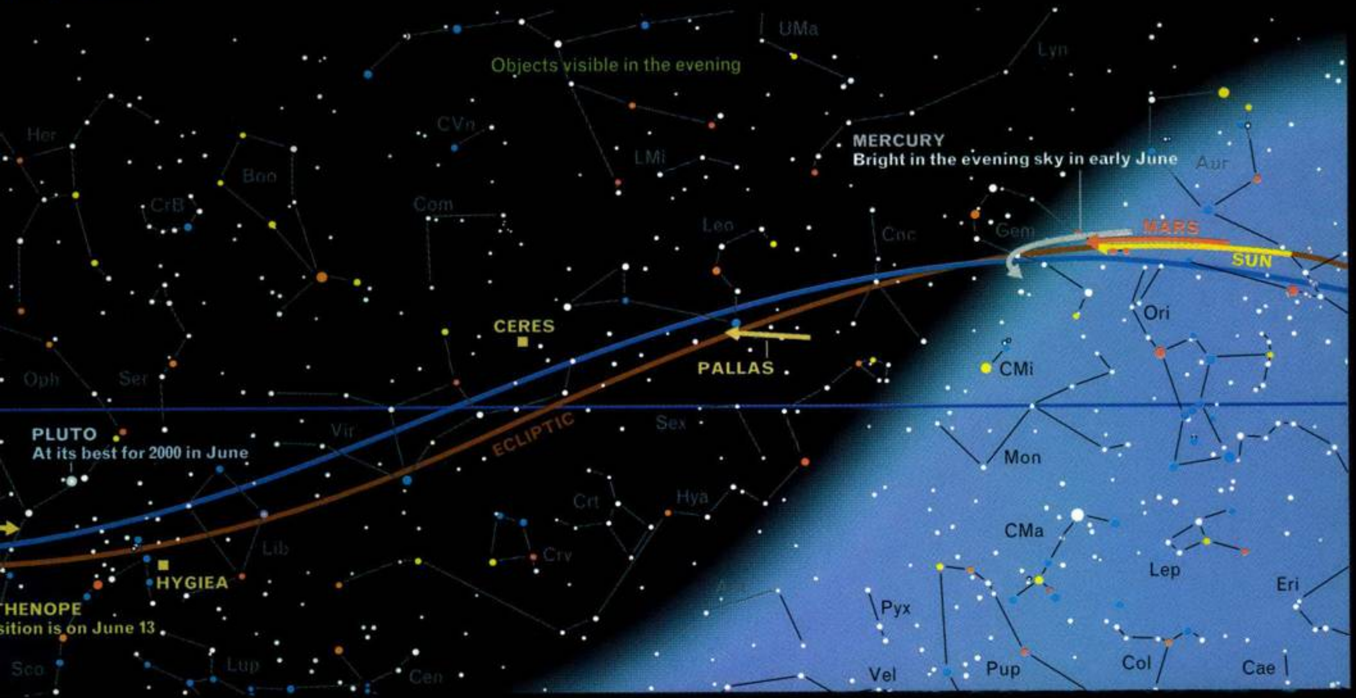
PLANETS	MERCURY	MERCURY	VENUS	MARS	JU
Date	June 1	June 15	June 15	June 15	Ju
Magnitude	−0.1	1.1	−3.9	1.6	
Angular Size	6.8"	9.2"	9.6"	3.6"	3
Illumination	56%	27%	100%	100%	1
Distance (AU) from Earth	0.985	0.731	1.735	2.585	5
Distance (AU) from Sun	0.382	0.448	0.720	1.575	4
Right Ascension (2000.0)	6h12.0m	7h15.4m	5h39.0m	5h55.5m	3h
Declination (2000.0)	25°34'	22°37'	23°36'	24°12'	1

Jupiter's Moons

Dots display positions of Galilean satellites at 5 A.M. EDT on date shown. South is at top to match the view in a telescope.



during the month.

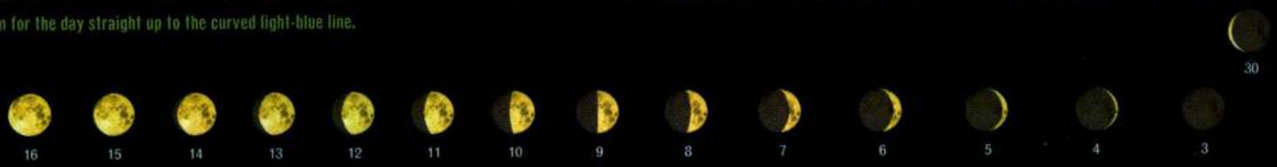

UMa
Lyn
Objects visible in the evening
Her
CVn
LMi
Aur
CrB
Boo
Com
Leo
Cnc
Gem
MARS
SUN
CERES
Ori
Oph
Ser
PALLAS
CMi
PLUTO
Vir
ECLIPTIC
Sex
Mon
Crt
Hya
CMa
Lib
Crv
HYGIEA
Lep
Eri
THENOPE
Pyx
Sco
Lup
Cen
Vel
Pup
Col
Cae

MERCURY
Bright in the evening sky in early June

PLUTO
At its best for 2000 in June

THENOPE
sition is on June 13

hown for the day straight up to the curved light-blue line.


30
16
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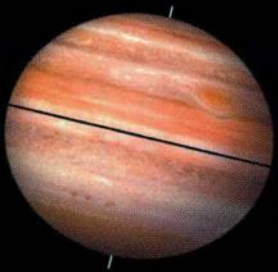
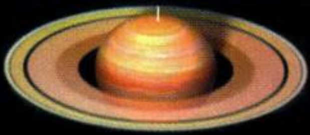
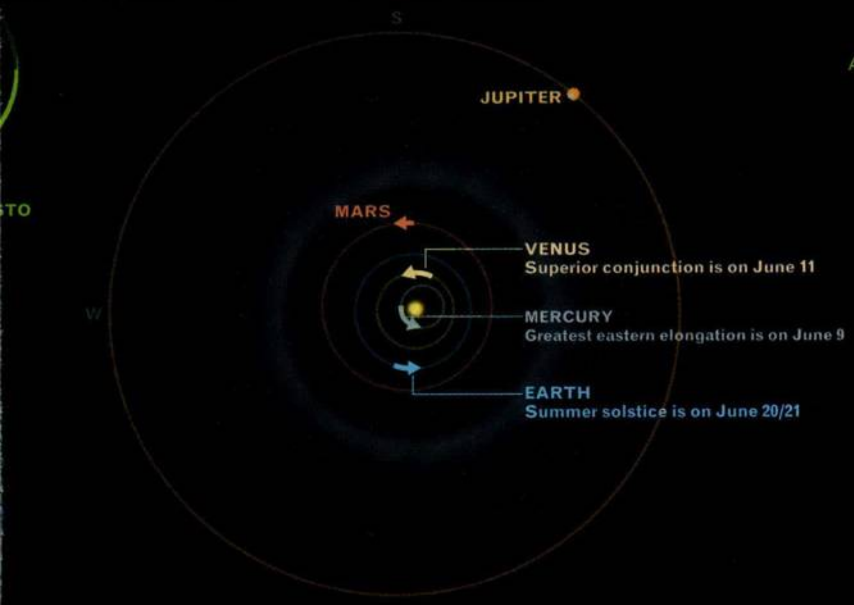




PITER	SATURN	URANUS	NEPTUNE	PLUTO
ne 15	June 15	June 15	June 15	June 15
2.0	0.2	5.7	7.9	13.7
3.6"	16.6"	3.6"	2.3"	0.1"
00%	100%	100%	100%	100%
.873	10.021	19.360	29.352	29.302
994	9.150	19.940	30.115	30.274
38.4m	3h32.0m	21h33.1m	20h34.1m	16h44.8m
°36'	17°02'	−15°17'	−18°31'	−10°56'

The Planets in Their Orbits

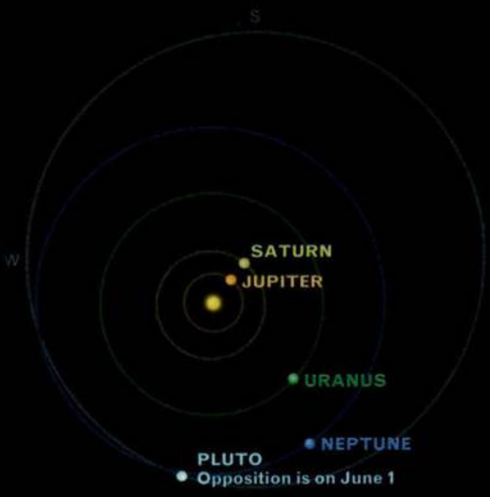
Arrows and dots show planets' positions during the month.


S
STO
W
JUPITER
MARS

VENUS
Superior conjunction is on June 11

MERCURY
Greatest eastern elongation is on June 9

EARTH
Summer solstice is on June 20/21


S
W
SATURN
JUPITER
URANUS
NEPTUNE

PLUTO
Opposition is on June 1

M13 vs. M92

It's no fun being benched, especially in the shadow of a great object such as the globular star cluster M13, the Hercules Cluster. The delightful globular cluster M92 would be a regular player if it were elsewhere in the sky.

The M stands for Charles Messier, who was a successful 18th-century comet hunter in Paris. His catalog of 110 clusters, nebulae, and galaxies has stood the test of time and remains the best list to cut your teeth on. (See our special Messier pull-out poster in this issue.) Most other nonstellar objects, from bright ones just shy of making Messier's catalog to really faint fuzzies discovered visually, ended up in the *New General Catalog* (NGC).

To the surprise of many amateurs, M92 is within reach of the naked eye from dark star-party skies. At magnitude 6.4, its soft fuzz is a good gauge for sky transparency. You'll want to find it first in binoculars to avoid confusion with a couple of nearby faint stars. M92 (R.A. 16h41.7m, Dec. 36°28') sits not far from M13 (R.A. 17h17.1m, Dec. 43°08') in Hercules, about two-thirds of the way on an imaginary line from Eta (η) to Iota (ι) Herculi.

M92 surpasses M13 in one major characteristic: density. Use an 8-inch or larger telescope to get an understanding of how the "density" of clusters can vary, and pump up the power past 150x. The higher the better, as long as air turbulence doesn't interfere. The stars keep packing in more tightly as you zoom into M92's bright core. In contrast, once you get about halfway into M13, you've resolved it. Sure, the sheer number of stars in M13 is impressive, but the "never-ending" feeling looking into the great depths of M92 is astonishing.

NGC 6210 is a challenging planetary nebula in Hercules. Jack Newton

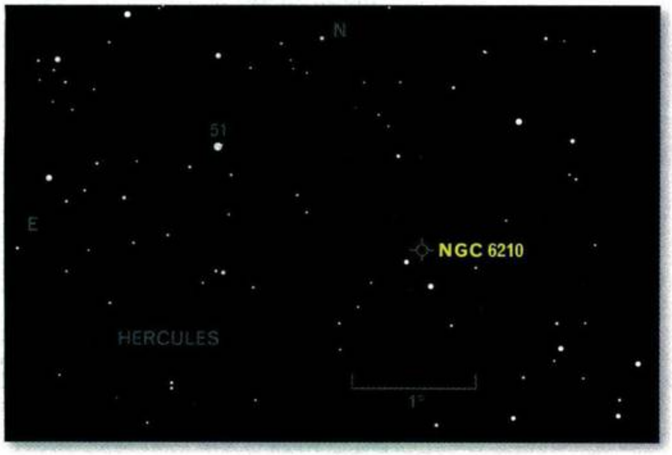
A Star's Dying Gasp

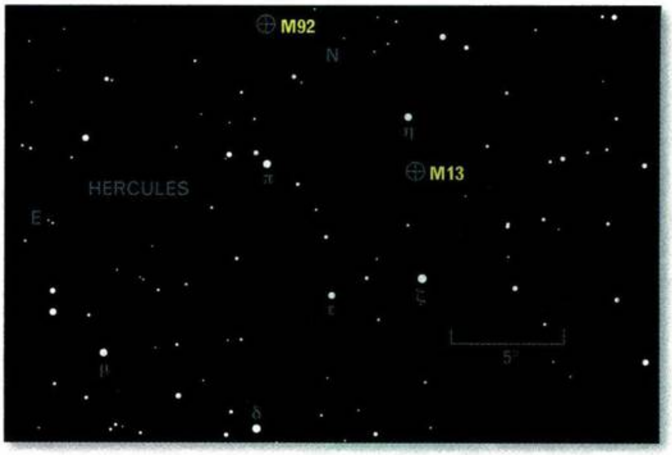
The last pages of a star's story are often spun out as a planetary nebula, such as NGC 6210. The great observer William Herschel coined the name planetary nebula because many of these puffed-out gas shells look a bit like Uranus through a backyard telescope.

Even in city skyglow, NGC 6210 stands out well thanks to it being small but bright, which is the same as saying it has a high surface brightness. It's about 14" across, appearing one-third the size of Jupiter's disk, and has a magnitude of 8.8. You can find it at R.A. 16h44.5m and Dec. 23°49', not far from 51 Herculi.

In a 5-inch scope from the suburbs, the disk is readily visible at 140x, but when you look right at it, NGC 6210 disappears. Your color-detecting cones aren't sensitive enough. Looking to the side with averted vision, your rods snap it up. Rapidly shift your view back and forth to make NGC 6210 into a blinking planetary.

Under urban skies with a 14-inch telescope I once noted NGC 6210 as "quite blue." What color can you see in a large scope?





sky Show

Predawn Planetary Visitors

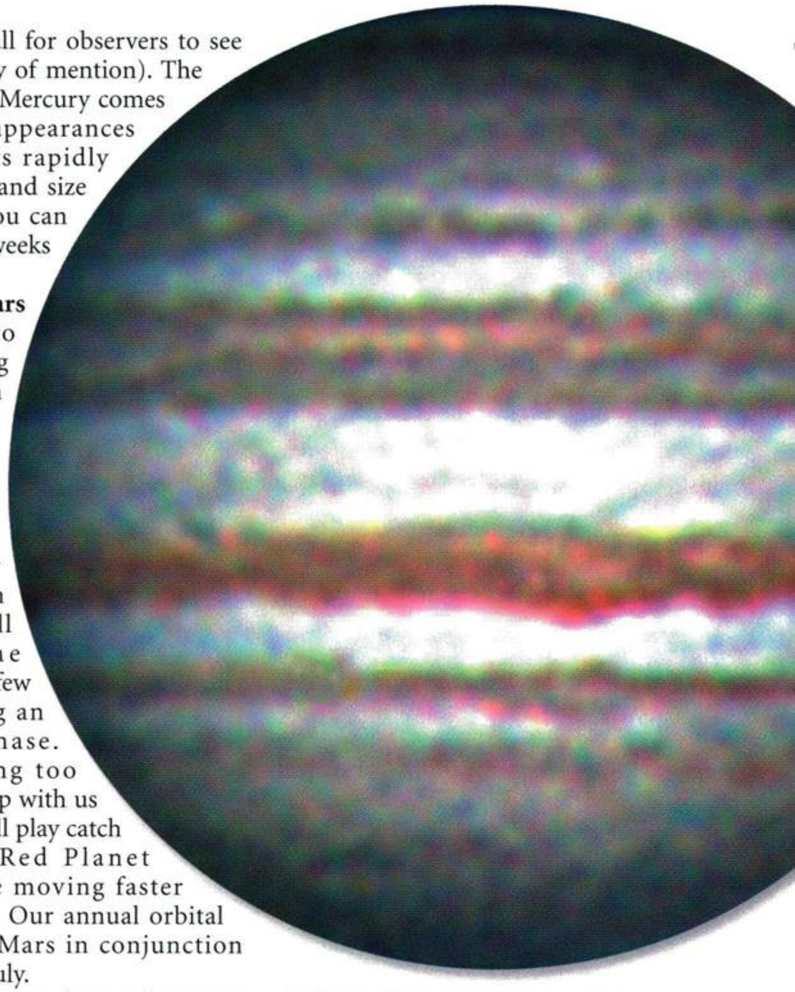
The first two weeks of June allow a brief but interesting glimpse of the innermost planet to the sun, **Mercury**. It will make a large arc into the sky before vanishing again below the horizon. The fleet-footed planet scoots up from the skyline during late May, and by June 1 it lies 7° above the horizon an hour after sunset at magnitude –0.1. On June 3 Mercury lies 4° north of the 2-day-old slender crescent moon, and both solar system bodies sit at the feet of Gemini the Twins. Catch the pair before the moon sets 90 minutes after the sun. Mercury is never easy to spot due to its relative closeness to the sun — its distance from the sun is never more than 43 million miles. At Earth's distance from the sun Mercury never strays more than 28° from our parent star. Therefore it appears this June in twilit skies, especially for more northerly latitudes where Mercury sets earlier and twilight lasts longer.

Try viewing the tiny disk of Mercury through a telescope, and you'll catch a 50-percent-illuminated planet on June 4 — it will be fatter than the moon on the same date. During the brief days of Mercury's visibility following June 4, Mercury will rapidly shrink to a crescent phase, reaching 25 percent illumination by June 16. On the same evening, Mercury lies very close (less than 2') to Delta Gem, a magnitude 3.5 star. During the same period, Mercury is moving between us and the sun and grows in apparent size — from a tiny 7" (tough to view clearly so near the horizon) to 10" (a little more respectable but still too small for observers to see any detail worthy of mention). The fascination with Mercury comes from its brief appearances and tracking its rapidly changing phase and size — something you can see within two weeks of observing.

In early June, Saturn has its closest conjunction with Jupiter for the next 20 years.

Howie Glatter

Venus and **Mars** are too close to the sun during June — both planets lie on the far side of the sun from our point of view. Venus passes superior conjunction on June 11 and will appear in the evening sky in a few weeks, showing an almost full phase. Mars is moving too slowly to catch up with us — instead we will play catch up with the Red Planet because we are moving faster around the sun. Our annual orbital motion places Mars in conjunction with the sun in July.



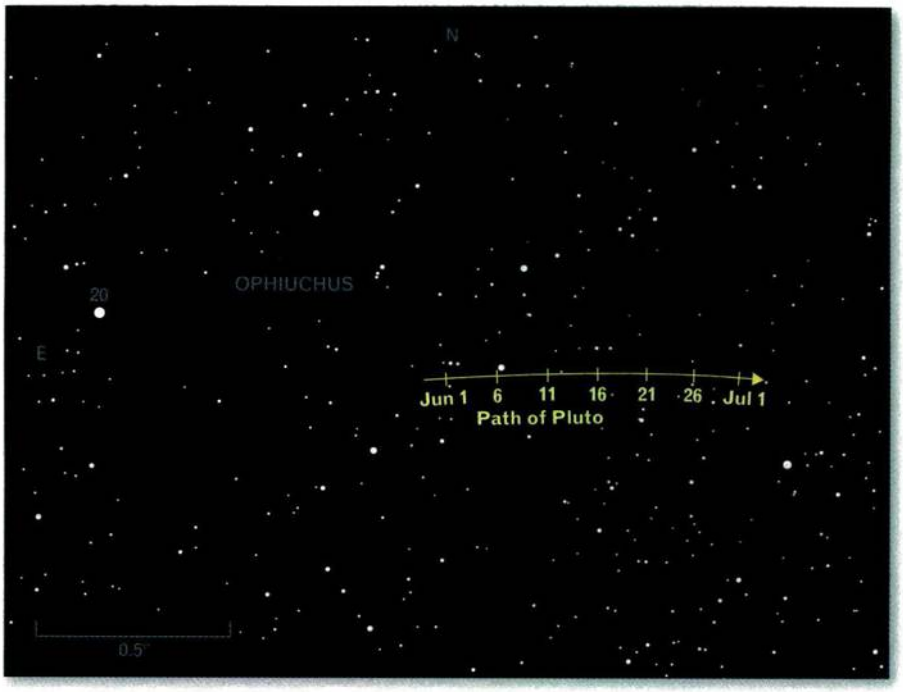
Jupiter and Saturn lead the sun into the morning sky in June. David Hanon

Jupiter appears to be moving away from **Saturn** after their conjunction late in May. You'll find them in the early morning sky in Taurus the Bull right before dawn. Both are just high and bright enough to catch an early view before sunrise. When your coworkers on first shift ask what that pair of gleaming lights was on the eastern horizon, you'll have an answer. Jupiter glows brighter at magnitude –2, and Saturn shines at magnitude 0.2. On June 1, 1.5° separate them — extending to 4° by June 30. This conjunction is the closest the two giant planets will be for 20 years and offers the great advantage of being able to easily slew your telescope from one planet to another quickly — the delicate turbulence of Jupiter's atmosphere contrasting with the tranquil elegance of Saturn's rings. The next close apparition is an exciting one — on December 21, 2020, Jupiter and Saturn will be at their closest for the entire century — less than 0.1° from each other — so close that Jupiter will occult some of the saturnian moons. So if you don't already have a telescope big enough to allow you to view Saturn's moons, you have 20 years to save for one.

Look for the waning crescent moon on June 28 lying 8° from Saturn and 12° from Jupiter. By June 30 Saturn lies 7° south of the Pleiades, with Jupiter only 5° from the star cluster. Any of these groupings would make for great portraits. (See our special section on how to take astrophotographs, starting on page 84.)

The best time to view the smallest planet in the solar system, **Pluto**, is on a moonless, inky-black night with the planet at its highest point above the horizon at midnight, which will give you the darkest possible skies. This point, when Pluto is exactly opposite the sun in the sky, is known as opposition and occurs on June 1 in the constellation Ophiuchus. With the new moon on June 2, the first week of the month is an ideal time to track down the dim ninth planet from the sun. Shining at magnitude 13.7, Pluto is a difficult challenge at best with an 8-inch scope. Larger scopes will ease the task, but Pluto's visibility still requires the most clear and transparent nights. Begin your search with the easy magnitude 2.5 star Zeta (ζ) Ophiuchi. Pluto lies within 2° of this star.

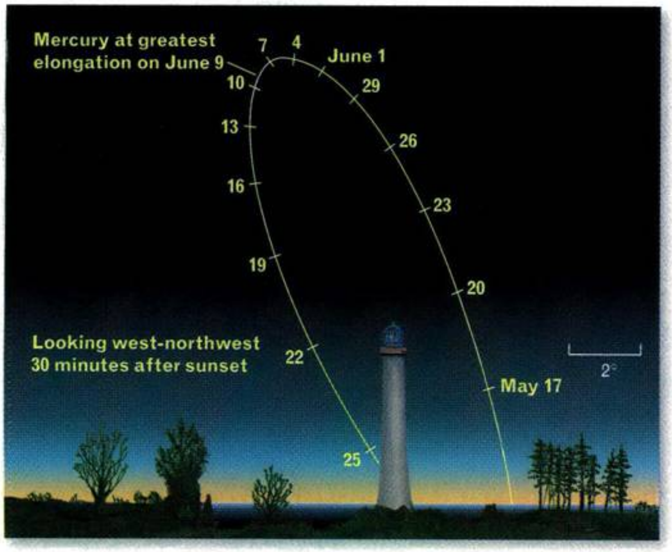
For an easier challenge, try to search out Pluto's neighbor, the eighth planet from the sun. **Neptune** reaches opposition next month and can be found in binoculars among the stars of Capricornus the Sea Goat. However, at magnitude 7.8, you need the aid of a star map to identify it. Memorize the stars in that portion of the constellation, and then when you find the one that does not belong, you've got it.

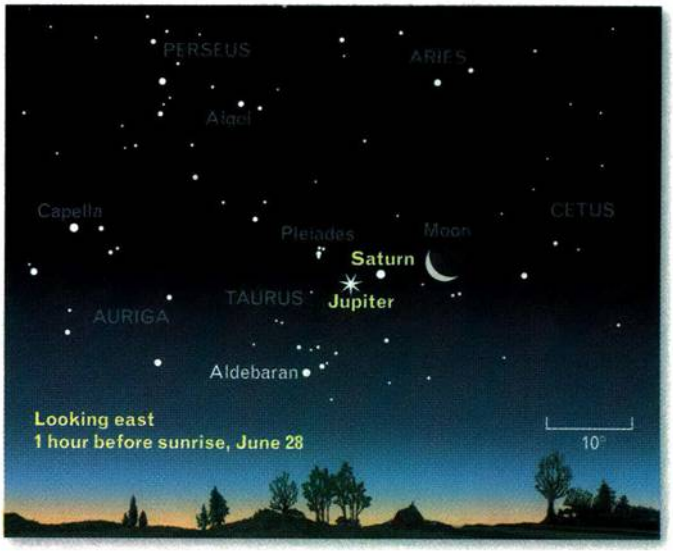

N
OPHIUCHUS
20
E
Jun 1
6
11
16
21
26
Jul 1
Path of Pluto
0.5°

The moon, just four days past full, stands 1.3° south of Neptune on June 20 — but its brilliance will all but smother Neptune's feeble glow. It's best to wait until darker skies prevail and search for the planet near the magnitude 6.7 star Omicron (o) Capricorni. Neptune moves a half degree closer to Omicron during June as the planet moves in a retrograde (westerly) direction against the stars. This apparent reverse path is caused by Earth overtaking Neptune in our faster, inner orbit.

At magnitude 5.7 **Uranus** shines brighter than Neptune, making it an easier target in binoculars. Look for a magnitude 3.7 star, Gamma (γ) Capricorni, toward the eastern edge of Capricornus. Uranus lies 2° northwest of this bright star. Uranus will be at opposition in August.

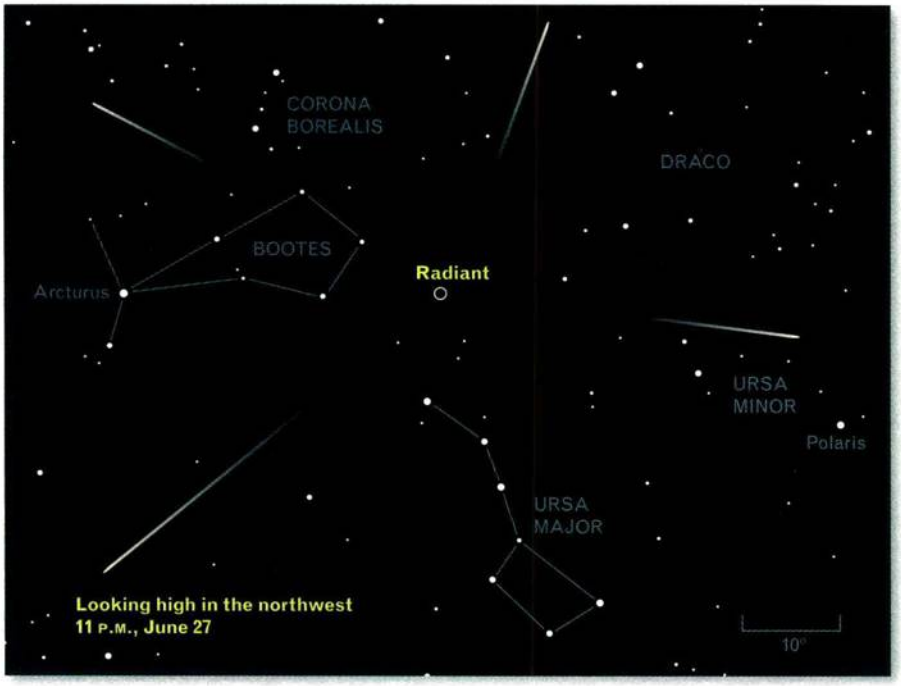
As the three outermost and trickiest to observe planets come into opposition in the next three months, you can hunt them all down and complete a goal of viewing all the planets.


Mercury at greatest elongation on June 9
7
4
June 1
10
29
13
26
16
23
19
20
22
25
May 17
2°
Looking west-northwest
30 minutes after sunset


PERSEUS
ARIES
Algol
Capella
CETUS
Pleiades
Moon
Saturn
Jupiter
TAURUS
AURIGA
Aldebaran
Looking east
1 hour before sunrise, June 28
10°

Sky Show

Meteors and Moons



Looking high in the northwest
11 P.M., June 27

A Duo of Showers

Some of the best meteor showers of the year can generate upward of 100 meteors per hour. Typically, on any clear night, an average of 7 meteors per hour can be seen. This rate, often called the sporadic rate, is a kind of background measure of debris entering Earth's atmosphere as seen by one observer located anywhere on Earth. There are many minor showers that don't generate the publicity of the Leonids or Perseids but are nonetheless occurring and can, on occasions, generate some spectacular meteors. During June two of these minor showers will bring about some overhead activity.

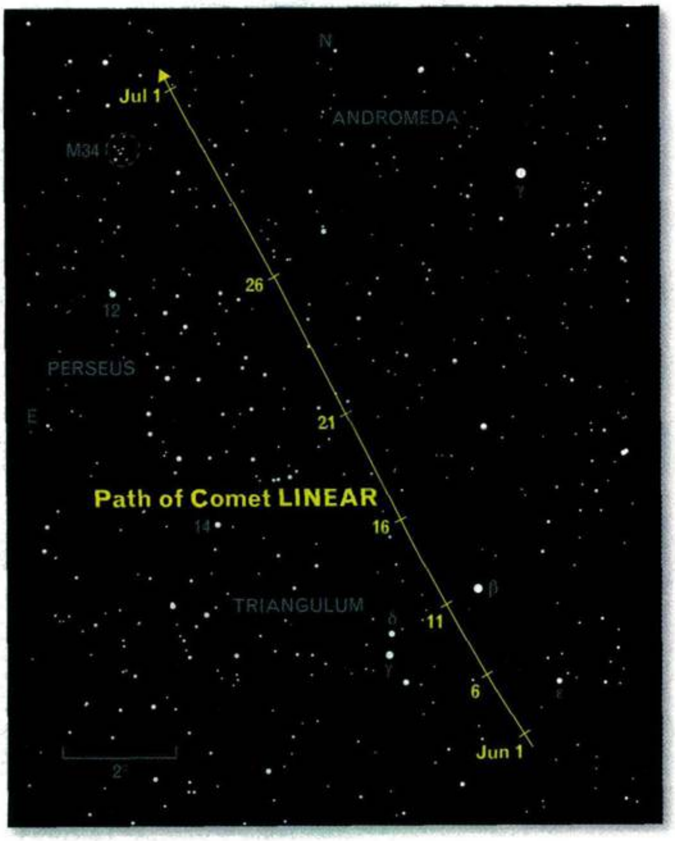
One of the main radio showers of the year, the Arietids, peaks on June 7, with activity lasting from May 22 through July 2. Short-wave radios can pick up the brief signal of distant radio stations being reflected off the ionized trails of meteors — much like the ionosphere reflects most radio waves. However, the radiant for this shower lies a mere 30° from the sun, so visual observing will be tricky. Lower latitudes, especially equatorial regions, have a better chance of viewing visual members of the shower, which appears to radiate from Aries the Ram as it rises the hour before dawn. This shower may be associated with Icarus, the most famous of Earth-crossing asteroids known collectively as Apollo asteroids.

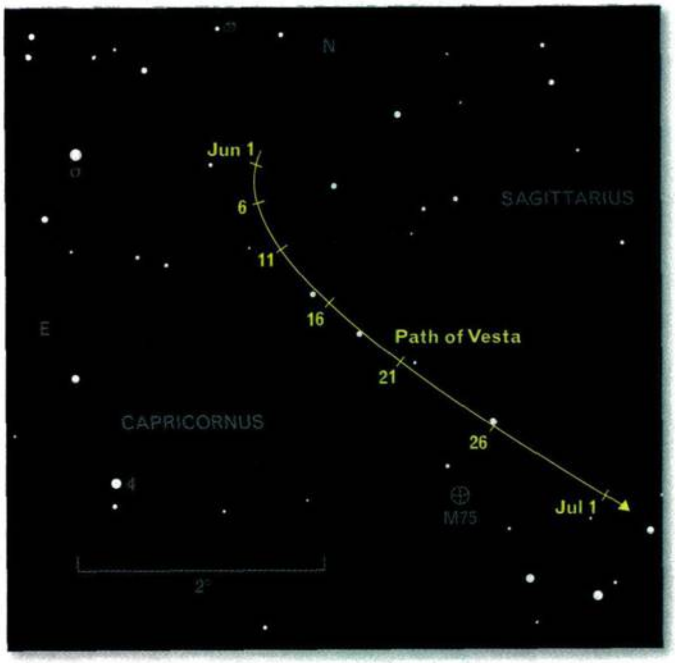
The June Boötids are a shower for which to watch out. Dramatic activity of this typically minor shower occurred in 1998. Rates of more than 50 meteors an hour for a dozen or so hours startled even veteran meteor observers. The shower has been active in only three previous years in the 20th century: 1916, 1921, and 1927. Last year's peak occurred during bright moonlight so no observations were possible, therefore no one knows what to expect for this year. The shower produces very slow-moving meteors with a velocity of only 11 miles per second — unusually slow for meteors. They appear to pass almost casually through the atmosphere compared to the fast-paced Perseids. Northern Hemisphere observers are well placed to view the radiant almost all night. The radiant lies in the northern part of Boötes the Herdsman.

The Moon in June

On June 16, the moon reaches its full phase. On days surrounding the full moon, meteor and deep-sky observing suffers from the brightness of the light reflecting off the moon. So target the moon instead — take time to familiarize yourself with the craters, rays, and maria. If you live on the west coast, you can compare your views of this month with those of next month, when a lunar eclipse occurs.

A full moon doesn't have to mean a night away from observing. Robert Gendler





Watch Comet LINEAR brighten as it moves toward its peak in July.

Tim Puckett

Comet LINEAR in Binoculars

Will Comet LINEAR (c/1999 S4) rise to naked-eye brightness in July? Until we find out the answer, we should prepare our observing skills for its arrival. Use binoculars to seek out any faint tails and structure within the inner glow of the comet.

To find this early morning interloper, choose your observing window and location carefully. A bright moon or light-dome from a city will wash out the outer envelope and make LINEAR look a lot smaller and fainter. Head east of large cities to keep the skyglow at your back. As for timing, the first two weeks have the moon in the evening sky. Even better, observe on the last early morning of June when the crescent moon is so thin it's harmless.

Retrain your eyes by taking five minutes to carefully inspect the inner and outer regions at each magnification. Start with 50–70x, then bump it up to 125–150x, and if the seeing conditions are steady, move to 200–300x.

Don't stop yet. Slowly step back down to wider fields, and you should be able to see things you missed on the way in. At lowest power, rock the scope back and forth with the comet just outside the field of view to see how far the tail extends. The eye is a great motion detector for ghostly features.

Check out http://encke.jpl.nasa.gov/, the Comet Observation Home Page, for up-to-date news.

A Naked-Eye Asteroid

The closest of the big asteroids, 4 Vesta, brightens past 6th magnitude this month. Even those without perfect vision can see it without binoculars.

Start the hunt at the lovely wide pair of stars Alpha^1 and Alpha^2 Capricorni. They're a delight in binoculars too. Drop straight south instead of following the chain of stars that makes up the necklace of Capricornus, and you'll end up near Sigma and 4 Cap. These will be your anchor stars; Vesta lies to the right (west). Because there are no other stars nearby with Vesta's brightness, if you see something flickering at the limits of your vision, you've found it.

The globular star cluster M75 floats near Vesta during the last week of June. Vesta slides less than 1° north of M75, so you should just be able to fit them both in one telescopic field of view at low power.

A different asteroid-globular conjunction takes place June 3–6. The asteroid 17 Thetis, at magnitude 10.1, moves less than 30' (one moon diameter) south of M107 in Ophiuchus, well suited for a late evening session. ■

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.

Getting Started

in Sky Imaging

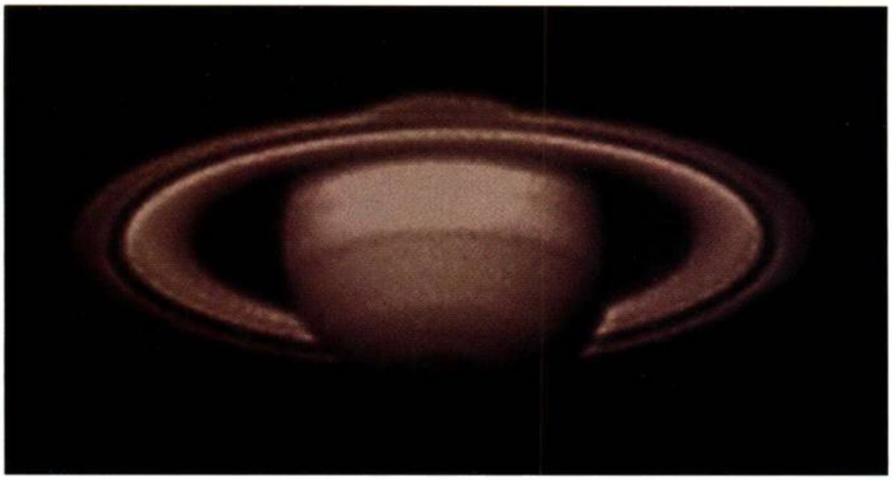
Simple cameras and off-the-shelf films make stellar portraits easy as 1-2-3.

by David Healy

DESPITE THE "CCD REVOLUTION," film is a long way from dead. Digital cameras are still limited in terms of capturing large areas of sky and resolution, while color films have gotten faster and sharper. The result is that it's easier than ever to make good conventional portraits of the moon, planets, stars, and galaxies. Improved films have made exposure times shorter and improved image quality and color fidelity. Professional sky photos your first time out? I don't think so. But better films and digital image processing shorten the learning curve for capturing good astrophotos.

A simple tripod with a camera fixed on top or a plain 35mm camera sitting atop a telescope makes it possible to capture numerous kinds of sky objects, including star trails, meteors, the moon, constellations, the Milky Way, occultations, gatherings of the planets, eclipses, comets, and landscapes with a celestial element. You can even produce your own photographic star atlas. Color portraits of star clusters, nebulae, and galaxies are possible with the more sophisticated guided, through-the-telescope photography.

Aurora borealis imaged with a 19mm lens, a camera set on a tripod, and fast color film. Paul Hanson



Through-the-telescope photography allows capturing closeups of Saturn. John Chumack

The key for beginners is not to feel frustrated if first results aren't "stellar." Astrophotography will seem counterintuitive at the outset even to experienced amateur photographers: It's dark, but you can't use a flash, and you're taking long exposures of subjects that are moving. These conditions do weird things to your favorite camera, to the roll of film that you bought at the supermarket, and to your mind, which will experience the 50-point drop in I.Q. that always results from going outside at night and trying to take pictures of the sky. This leads us to Healy's three principles of astrophotography: (1.) keep at it, (2.) keep good records, and (3.) take lots of pictures and throw most of them away.

Selecting a camera is, surprisingly, a nontrivial subject. It turns out that today's gadget-laden electronic wonders, though they take wonderful snapshots, would rather die (or at least exhaust their batteries) than take a half-hour exposure. As far as films are concerned, I have conducted controlled real-world astrophoto tests of ten 35mm films and found at least one surprising winner as well as several losers.

Start with the Right Camera

However wonderful they might be for eliminating human error in snapshots, the auto-focusing, auto-exposing, multimetered, coffee-making, 21st-century 35mm cameras that now dominate new-camera sales are poor matches for astrophotography. Composing an astronomical photograph in the viewfinder of a typical 35mm camera is difficult because the viewfinder is designed for the light levels found in your backyard in mid-afternoon and not in the middle of the night. Simply put, even if you can find it in the sky, you probably still can't find it in the finder.

Lots of beautiful astronomical photography has been done with medium to large format cameras. From my point of view, however, the best astronomical camera is a simple, fully mechanical 35mm camera body that will accept interchangeable lenses and whose shutter can be held open with a locking cable release. It should also have a bright viewfinder and be equipped, if at all possible, with an accessory right-angle attachment for the finder. The first time that you can't see your target in your camera's finder because your head, not being three inches wide, won't fit between the telescope and its mounting, will make you appreciate the right-angle attachment.

New, fully manual 35mm cameras are scarce and expensive; fortunately an active used-camera market exists. Two places to start your search are your local camera shop and the mail-order camera-store ads in the back of such magazines as *Popular Photography*. What brand and model used camera should you purchase? As you move from fixed-camera and piggyback photography to through-the-telescope photography, having a bright viewfinder becomes increasingly important. With the former two methods, focusing consists of turning the focusing ring on your lens to infinity. With through-the-telescope photography, however, focusing is critical, and focusing on a star becomes difficult-to-impossible with a dim viewfinder that was designed for snapshot photography. The answer to this problem is to select a used camera model that has interchangeable focusing screens and acquire a focusing screen that was designed for low-light levels.

Orion Telescopes and Binoculars offers "ultrabright" focusing screens, and I would suggest concentrating your camera-body search on the following camera models, for which Orion offers focusing screens: Olympus 1–4, Nikon FE/FE2/FA/FM2, Nikon F3, Nikon f/F2, and Pentax LX.

Is the Night Sky Really Green?

Astrophotographers are faced with a bewildering array of film choices: color or black-and-white, slide or print, Kodak or Fuji, ISO 100 or ISO 1600, supermarket or mail-order, standard or hypersensitized, PJ 400 or Portra 400 VC, to name just a few. Which is best? The answer, unfortunately, varies.

When films record faint light over time, they suffer from an affliction called reciprocity failure. In ordinary snapshot photography reciprocity rules: A photograph, if properly exposed at a shutter speed of 1/500 of a second and a

FILMS FOR ASTROPHOTOGRAPHY

Film	Type	Hypered	Speed	Color Fidelity	Resolution
Kodak PPF 400	Color negative	No	Fair	Good	Good
Kodak PPF 400	Color negative	Yes	Good	Good	Good
Kodak PJ 400	Color negative	No	Good	Good	Excellent
Kodak 400 VC	Color negative	No	Good	Poor	Fair
Fuji G 800	Color negative	Yes	Good	Excellent	Good
Kodak P1600	Color slide	No*	Good	Excellent	Poor
Kodak P1600	Color slide	Yes*	Excellent	Fair	Poor
Fuji RD 100	Color slide	Yes	Poor	Fair	Superb
Kodak TP 2415	Black-and-white	Yes**	Good	—	Excellent
Kodak TMY 400	Black-and-white	No	Fair	—	Fair

*With "Push 2" processing

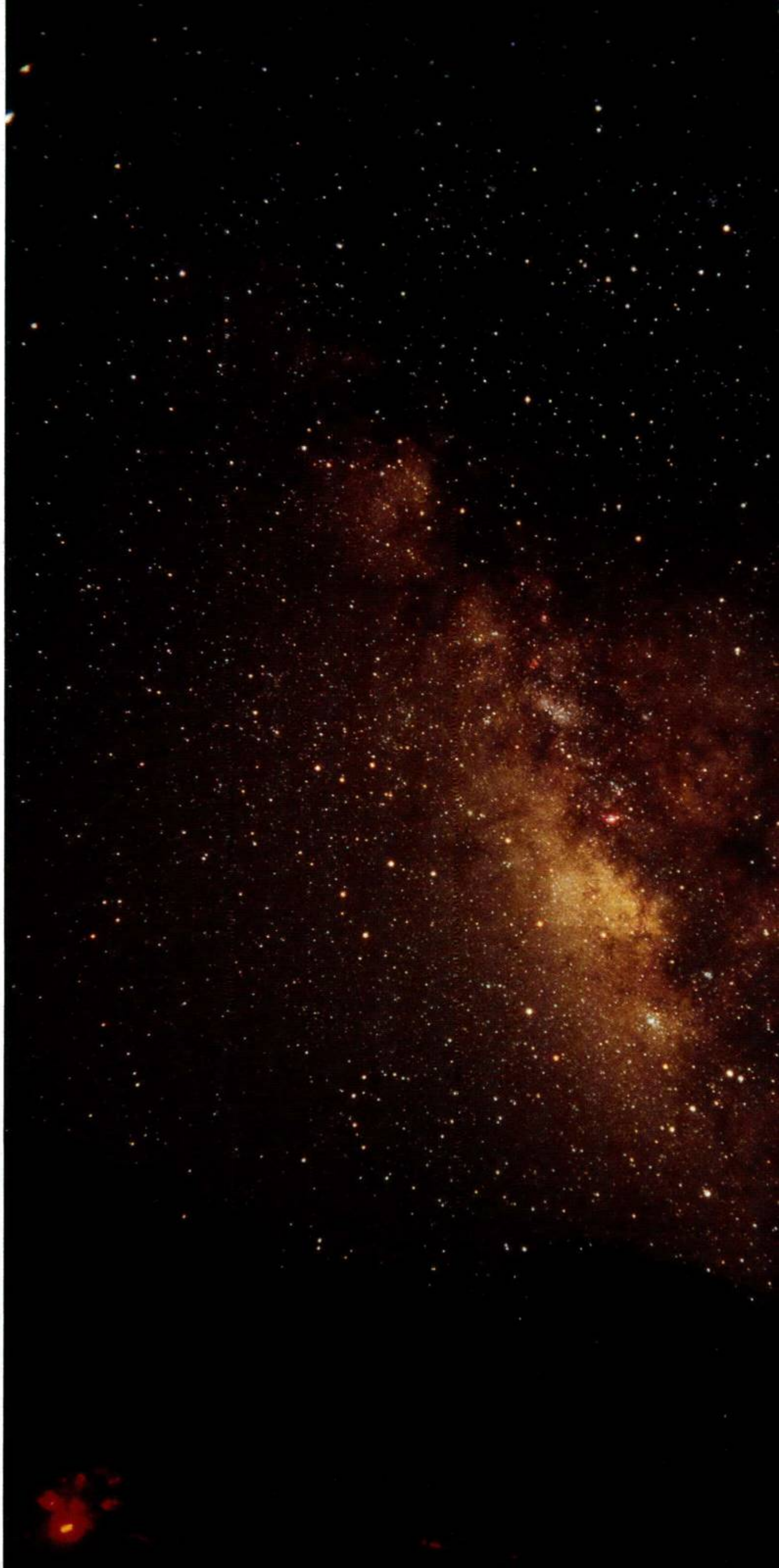
** Developed in D-19 for 5 minutes at 72° F focal ratio of f/8, will also be properly exposed at 1/250 and f/11 and at 1/1000 and f/5.6. In other words, doubling the area of the lens opening and cutting the exposure time in half results in a properly exposed picture, as does cutting the lens opening in half and doubling the exposure time. This reciprocity rule begins to break down with many films in time exposures of more than 30 seconds. A film with an ISO rating of 400 used for snapshots might well have an effective rating of 25 or even zero if used for a one-hour exposure of the Helix Nebula at f/10. An even more insidious effect is that the three layers in a color film may lose reciprocity at different rates, dramatically changing the photo's color balance.

Yes, the natural skyglow of even dark rural skies is greenish, but you don't have to use films whose reciprocity characteristics exaggerate the greenish skyglow. At the risk of oversimplification, it's okay to use your favorite print or slide film from the bin at Walmart (i.e, Kodak Gold or Fuji Superia or Sensia) if you are taking short exposures of bright objects. An example would be a 5-second exposure of the crescent moon and Venus setting over the mountains at twilight, or a 1-second photo of a lunar eclipse.

Creative Film Sources

Longer exposures require somewhat more exotic films that you probably won't find at the supermarket. The photographic mail-order houses that advertise in the back of such magazines as *Popular Photography* offer a wide assortment of films. One retailer that particularly caters to amateur astronomers is Adorama. And Lumicon is perhaps the best source of astronomical film and related supplies and equipment for skyshooters.

Lumicon offers, by mail order, many of the best films for astrophotography and was the source of the hypersensitized films that we used in our film tests. Hypersensitizing consists of baking a roll of film in a mixture of gases containing hydrogen for up to several days. The advantage of hypersensitizing is that the treated film increases or at least maintains its rated speed or sensitivity under the low-light, long-exposure conditions typical in astrophotography. The disadvantage



Tracking a camera to follow the stars makes possible stunning Milky Way panoramas like this one exposed over 20 minutes. Chris Cook

of hypered films is that the effect of hypering wears off sooner or later (freezer storage retards this degrading process); it needs to be exposed and processed promptly. Lumicon offers kits for hypering your own film, which is preferable if you expect to use hypered film frequently.

SUGGESTED EXPOSURE TIMES (MINUTES) AT F/5.6

Film	Type	Hypered	Orion Nebula	Andromeda Galaxy
Kodak PPF 400	Color negative	No	20	40
Kodak PPF 400	Color negative	Yes	12	30
Kodak PJ 400	Color negative	No	5	25
Kodak 400 VC	Color negative	No	15	20
Fuji G 800	Color negative	Yes	15	30
Kodak P1600	Color slide	No*	15	25
Kodak P1600	Color slide	Yes*	4	10
Fuji RD 100	Color slide	Yes	45	50
Kodak TP 2415	Black-and-white	Yes**	15	35
Kodak TMY 400	Black-and-white	No	20	40

*With "Push 2" processing

** Developed in D-19 for 5 minutes at 72° F

Testing the Films Side-by-Side

I acquired samples of ten different types of film, both hypered and unhypered, from Lumicon and Adorama. All the selections had at least some promise as films that might behave well when used for long exposures of faint objects. I ran all ten through identical tests. Using a 300mm telephoto lens "piggybacked" for tracking on an equatorially mounted telescope, I took exposures of the Andromeda Galaxy (M31) and the Orion Nebula (M42) at lengths ranging from 5 minutes to 40 minutes and at focal ratios ranging from 4 to 8. All the tests were done on clear moonless nights from my dark-sky site in southeast Arizona. Although the exposures were taken over a period of about two weeks, sky conditions were similar, if not identical, for all the tests. With the exception of the Technical Pan 2415 film, which I developed myself, all the film was processed at the same laboratory.

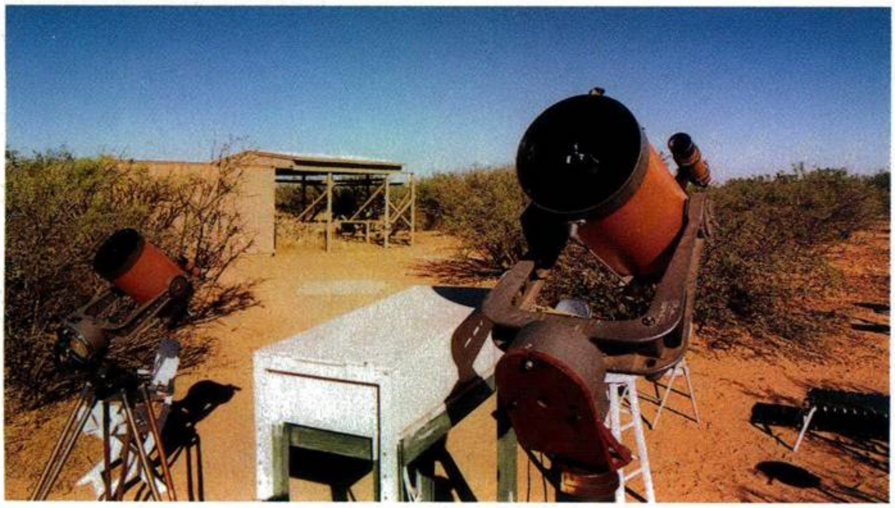
I selected M31 and M42 as targets for the test not only because they are well-known objects commonly shot by astrophotographers, but also because the objects offer wide variations in both brightness and color. M31's spiral arms grow increasingly fainter the farther one goes from the nucleus of the galaxy, finally blending with the sky background, and M42 is adjacent to the reflection nebula NGC 1973–5–7.

Kodak PPF 400 color print film has been the gold standard among astrophotographers for many years; inevitably, Kodak has discontinued it, recommending instead the use of Portra 400VC. Lumicon still has supplies of PPF 400 at this writing, but I'd recommend PJ 400 color negative film instead of Portra 400VC if PPF 400 is not available (or even if it is). Fuji's strong entries in color astronomical films are G800 for prints and RD 100 for slides. Kodak's high-speed Ektachrome P1600 slide film has both the virtues and vices you might expect. I tested Kodak's fast TMY 400 black-and-white film as a possible alternative to hypersensitized Technical Pan 2415, the best black-and-white film for astronomy. TMY 400 failed; use TP 2415 for black-and-white photography — it's well worth the trouble of developing it yourself. The table (p. 86) shows my test ratings of the films on three criteria: speed or sensitivity, color fidelity, and resolution (i.e. graininess or sharpness).

A few points that stood out: Kodak's new PJ 400 color print film, even though it wasn't hypersensitized, was as fast as the discontinued PPF 400 and was less grainy. It may well become the astrophotographers' new gold standard. Fuji's G800 color print film, at least when hypersensitized, is an all-around fine choice. Fuji's RD 100 color slide film yielded the finest detail and resolution of all the films tested; perhaps the finest I have ever seen. It also produced a sky background of a deep forest green and took long exposure times to record the detail properly, even when hypersensitized.

Another table (above) presents recommended exposure times for the tested films for M42 and M31, converted to a standard focal ratio of 5.6 . Bracket your exposures, at least on the low side. These exposure times are long enough to reach the sky fog limit at a dark site: longer exposures would merely record the sky background with more density without increasing detail. The more light-polluted the site, the shorter the exposure.

Get yourself a camera body and roll of one of these films and go out and shoot. And keep shooting. Wait until a night when the sky is dark and transparent (unless you're shooting the moon). The only way to get good at astrophotography is to go outside and do lots of it. You'll shoot a good many rolls before you begin to feel comfortable with all the variables involved. The sooner you start, the sooner you'll be collecting your own portraits of the ever-changing universe.



Long-exposure deep-sky photography captures the Horsehead Nebula in Orion (opposite page). The author's setup, used for astroimaging, is dubbed "Junk-Bond Observatory" (below). Michael J. Grady (left) and David Healy

Basic Equipment,

Majestic Photos

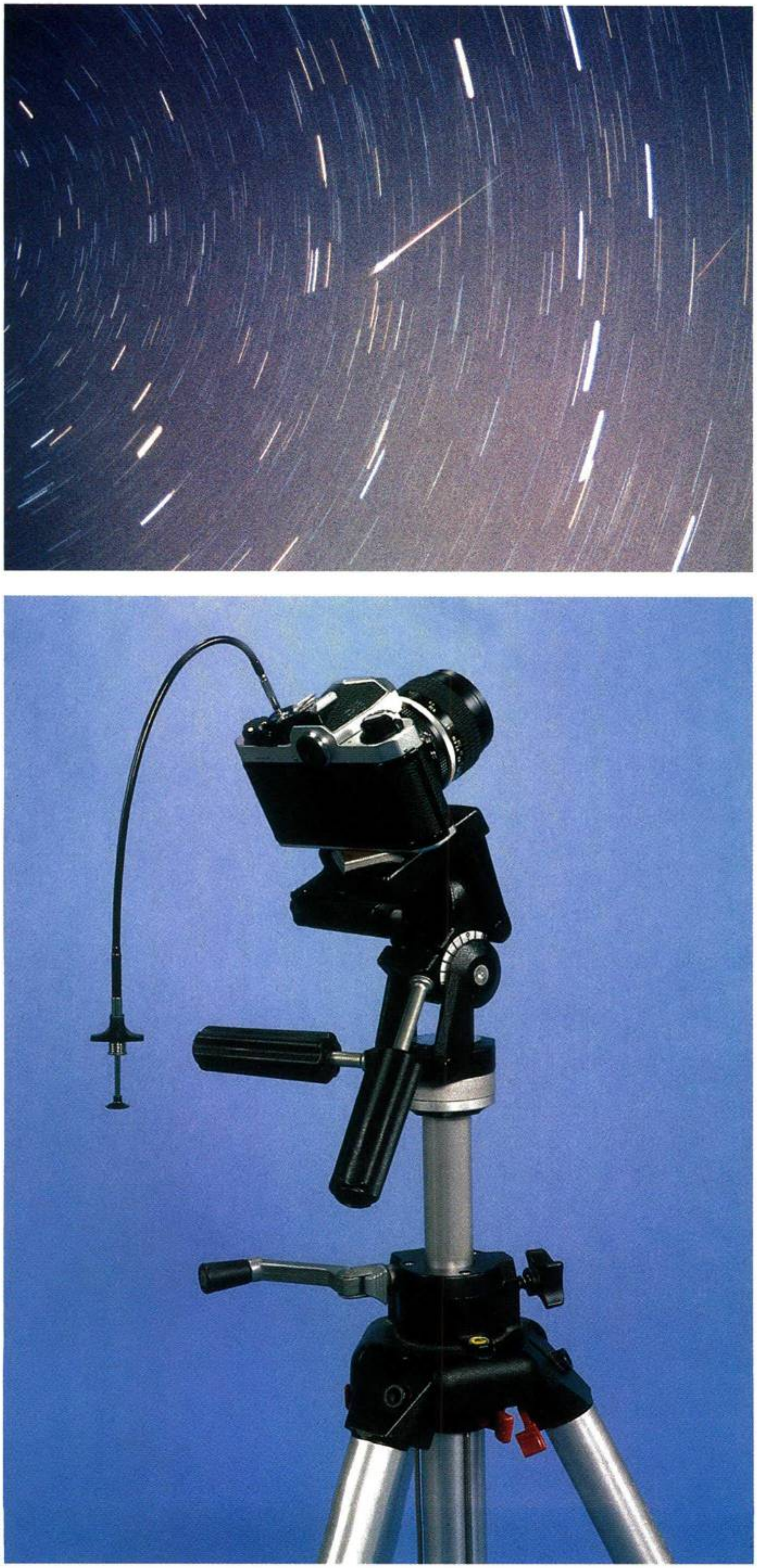
To become an astrophotographer all you need is a 35mm camera, an inexpensive tripod, and a cable release.

Text and Photographs by David Healy

I MUST HAVE LOOKED LIKE A SLAPSTICK COMEDIAN during my first attempts at astrophotography as I fumbled with my camera and tripod. One of my first photos was an accidental shot of my right shoe. It was out of focus. Later, I either forgot to put film in the camera or take the lens cap off. I neglected to turn the shutter wheel to the "B" setting, and as a result I took an exposure of 1/125 second instead of 30 minutes. Darkness was disorienting: I tripped over the tripod during a time exposure and another time I lost my cable release amid fallen leaves. Eventually, I got the hang of it, and now I rarely focus at 3 feet while photographing the Andromeda Galaxy, which is roughly 2.5 million light-years away. (Always set the camera's focus on infinity.)

As you may suspect, I'm not an award-winning photographer. But I have beautiful celestial images in my photo albums. Without any exotic equipment, you, too, can capture constellations, moon-planet alignments, and meteors. You can create your own atlas of the sky overhead. All you need is a 35mm camera, a camera-store tripod, and a cable

A red light, airplane trails and star trails shine in this 45-minute exposure at Lowell Observatory.



Astronomy

release to hold the shutter open without jiggling the camera. If I can do it, so can you.

Beginning

Start on a clear, moonless night by loading fast color film into your camera and attaching it to a tripod. In the Northern Hemisphere, set the lens aperture wide-open, move the shutter speed to the B (bulb) setting, and point the camera at Polaris. Use a lens hood, and a hair dryer if necessary, to keep dew from forming on the lens.

Use a cable release to bracket your exposures: Take exposures of 5 to 40 minutes. Remember to vary your exposure times from what you consider too brief to far too long. Likewise, vary the camera's aperture setting from a wide-open f/2.8 to a pinhole f/22. The resulting star-trail photographs will illustrate the apparent rotation of the sky around the North Celestial Pole. Urban light pollution may wash out your exposures, but taken at a dark site your images will show the colors of stars. Welcome to astrophotography.

Keep a record of exposure times and f/stops, weather conditions, light pollution, and sky conditions. Compare your images to those notes. You will learn to estimate the "sky fog limit" of your site — the longest exposure beyond which the background illumination of the sky cancels out any benefit gained with a longer exposure. Of course, your first pictures won't rival Ansel Adams's, but keep trying. As with any skill — from comedy to photography — persistence is required.

In photographs taken just after sunset or before sunrise you may capture a satellite trail. Much less frequently, during the middle of the night, you may catch a meteor trail. The variation in star-trail length illustrates the apparent east-to-west motion of the sky, which causes stars to trail. Take another set of time exposures of the sky at the celestial equator, which is 90° away from Polaris. In these photos, note that the star trails are straight and much longer. Star trails are shortest and most curved near Polaris. They become straighter and less curved farther away from the North Star, becoming straight at the equator. At

Top to bottom: A pair of Leonid meteors streaks across the November sky during a 15-minute exposure. A 35mm camera, tripod, and cable release are basic equipment.

the celestial equator these lines elongate at a rate of 15° per hour of camera exposure. Thus you can take a portrait of the Big Dipper (which is closer to Polaris) using a longer time exposure than you can of the Orion constellation, which is on the equator.

The amount of trailing in your photographs also depends on the focal length of the lens used: at a given exposure a wide-angle lens will yield shorter or invisible trails while a telephoto lens will show longer, brighter trails.

Optical Limitations

Imaging point sources of light is a revealing test for camera lenses. Stars near the center of the image may be points, but stars at the outer edge of the field look like blobs. Why? All but the best lenses lose quality near their edges. Specialized lenses — for example, those with zoom features or with low focal ratios — have even poorer edge-of-field quality, which is most apparent at full aperture.

Stopping down the shutter often will improve image quality. My inexpensive 17mm wide-angle lens has distortions when the aperture is wide open at f/3.5. However, stars become sharp — even at the edge of photographs — when I adjust the aperture to f/5.6 and lengthen the exposure times. It's a trade-off: image quality can be increased, but more time is needed. However, when you increase exposure times the motion of stars will make them trail across your film. I can reduce exposure times by using faster films, but they yield grainier images. If your camera's lens produces sharp star images all the way to the edges — even when the aperture is wide open — you have a treasure.

Meteors and Star Trails

Your chances of photographing a meteor are slim, but they are better while taking long-exposure star-trail photographs in the early morning during the Perseid, Leonid, Geminid, or other annual meteor showers. Don't point the camera at the source of these showers. Meteor trails are longer the farther away from the constellation from which they arise. Meteors, which may look bright to your naked eye, look dim on film because they flash too briefly. For the best results, adjust your camera to full aperture and use faster film. The distorted edge-of-field effects that many photographers find so objectionable in short exposures should give you wide, colorful star trails.

Venus appears to rest momentarily on the moon during this 1974 occultation.

Master the Moon

Because the full moon is sunlit you can photograph it as if taking a backyard snapshot in the afternoon. The moon at partial phases is side-lighted or back-lighted: in these circumstances use a lens aperture that is about one stop wider for a gibbous moon, two to three stops wider for a quarter moon, and three to four stops wider for a crescent moon.

Unfortunately, the angular size of a full moon is only about 0.5°. Since a normal 50mm lens covers 38° of sky, you could fit 76 full moons in your picture. Don't expect to see crater details in an enlargement. Good lunar portraits require a telephoto lens or telescope. When using a short-focal-length lens to photograph the moon, try giving it interesting company — bright stars, planets, mountains, sunrises, or sunsets.

Shooting Constellations

With the help of our lens-coverage table (p. 98) and a star atlas you can plan portraits of your favorite constellations and star groupings. Rectangular paper or transparent overlays that match the sky coverage of your lenses will help you plan photographs. You may not immediately recognize your pictures because fast film, a short focus lens, and a moderate f/stop such as 5.6 will capture many stars too dim to see with your naked eye. These pictures can be taken with exposure times brief enough to prevent star trailing.

A Personal Star Atlas

In mid-northern latitudes, about 30,000 square degrees of the entire 41,000-degree sky rise far enough above the horizon during a year to be photographed. A 17mm wide-angle lens covers 6,000 square degrees of sky, so theoretically you could cover the entire visible sky with five photographs. A 50mm lens covers 1,000 square degrees, so you could create a complete star atlas from your site with only 30 photographs, although 60 would provide overlapping coverage. Your photographic star atlas won't rival the Palomar Sky Survey, but it will add immeasurably to your knowledge of the night sky.

The Next Step

You may eventually outgrow your tripod. Star trails may become passé. The next step in astrophotography is surprisingly easy: mount your camera on a telescope platform with a motor drive that tracks the sky. This setup permits much longer exposures and yields more rewarding photographs. One last point: remember to send your best shots to *Astronomy*'s photo editor for possible inclusion in the magazine's Hot Shots department. ■

A Simple Guide

to Piggybacking

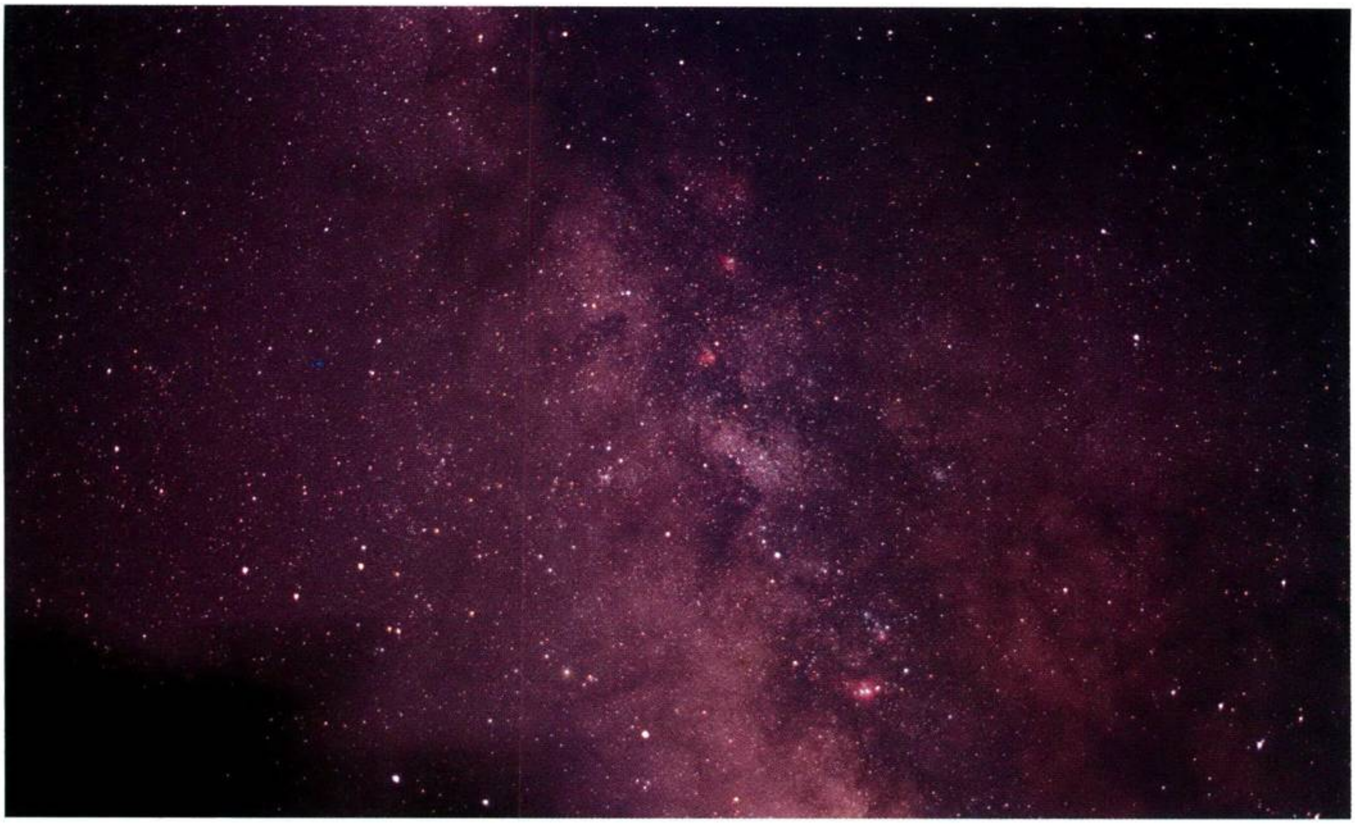
Avoid unwanted star trails and smears by tracking your camera.

Text and photographs by David Healy

ANYONE WISHING TO CAPTURE the subtle hues of nebulae and galaxies while avoiding telltale star trails and smears needs to keep one word in mind: "piggyback." But before you take a running leap onto your neighbor's back, grab your camera and attach it to your telescope instead. Add an equatorial mount or other platform that follows the sky, and get set for dynamic pictures that reveal more detail and color than you ever expected.

As discussed in "Basic Equipment, Majestic Photos" (p. 90), stars become trails and images of extended objects smear as Earth rotates during prolonged exposures. This is a common problem when exposure times last beyond the limits imposed by the focal length of the lens and the declination of the object. Piggybacking allows for long exposures (say from five minutes to an hour or more) without the artifacts caused by imaging with a camera on a stationary tripod.

An occultation of Venus was shot using the piggyback technique.



Piggybacking captures wide starfields like the Milky Way in Sagittarius.

Piggybacking works on any mounting that offsets Earth's motion, especially when using short-focus lenses. You can mount a camera with a long-focus lens on a motor-driven telescope that is polar aligned and make guiding corrections to keep stars from trailing. Telescope manufacturers such as Meade and Celestron offer accessory camera mounts whose threads fit the ¼-20 pattern of a 35mm camera's tripod socket. Orion Telescopes and Binoculars carries an array of piggyback camera adapters, including swivel-tilt models that permit independent camera movement, regardless of the plane of the telescope.

Unfortunately, scopes with altazimuth mountings — although they are fine for visual observing — are inappropriate for piggyback photography because of a phenomenon called "field rotation." Long exposures taken with cameras attached to telescopes with altazimuth mountings cause images near the edge of the field to make trails around the center of the photo, much like a polar star-trails photo. This occurs because the orientation of the field of view gradually changes as the telescope tracks to the west. Some altazimuth-mounted amateur telescopes offer a device called a "field de-rotator," which compensates for this effect, but only when the camera is mounted at the prime focus of the telescope itself.

For piggyback photography, use a telescope whose right ascension (or polar) axis can be pointed (in the Northern Hemisphere) at the North Celestial Pole.

Polar Align Your Telescope

Accurately aligning your telescope's mount so that it "tracks the sky" is a prime requirement for astronomical imaging. This is particularly true if you plan to piggyback long-focus lenses (i.e., lenses with more than a "normal" lens's 50mm focal length) or when attaching your camera or CCD to the telescope itself — in effect, turning the entire setup into a huge telephoto lens. Be aware that higher magnification means more magnification of tracking errors. Furthermore, locating a celestial target with setting circles or with a "go-to" mounting proves much easier with a precisely aligned telescope. In astrophotography, a good polar alignment makes all the difference. Take your time: The alignment method doesn't matter as long as the right ascension (i.e., east/west) mechanical axis of your telescope points precisely at the celestial pole.

It takes as little as five minutes to use your telescope's finder to achieve an alignment accurate enough to find targets for short-focus piggyback photography. Primarily used with fork-mounted telescopes, this method adapts to other mountings as well. First make sure that your finder is collimated with your telescope; in other words, the finder and telescope should point in exactly the same direction. This is most easily done in daylight, especially if this is your first attempt. With the drive off, point the telescope at a distant object. Then move the finder's adjustment screws until the same target is centered in the field of view of the finder.

After dark, with the drive on, center a bright star in the finder, then center it in the telescope's eyepiece as well. Next, move the finder's adjustment screws to re-center the bright star at the intersection of the crosshairs. Finally, check to make certain that the star is still centered in the telescope's eyepiece. If not, repeat the process.

Orient the finder's crosshairs so that they parallel the declination and right ascension axes of the telescope. To check this, center a bright star on the finder's crosshairs and move the telescope in declination (north/south) or in right ascension (east/west). The star should travel along the finder's crosshairs as you move the telescope. If not, rotate the finderscope in its mounting. Then recheck the collimation to make sure that the finder and telescope are still aligned.

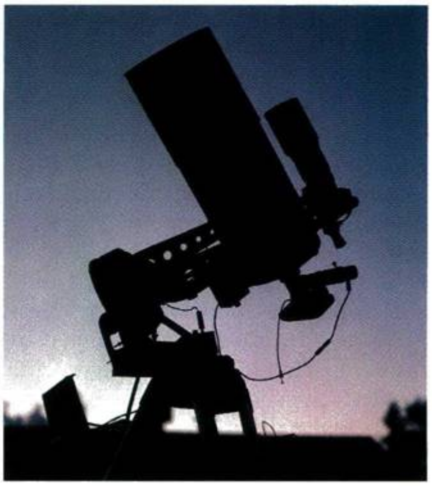
Determine your finder's field of view. With the telescope's drive off, watch as a star on or near the celestial equator drifts across the center of the finder's field of view, bisecting it. An easy-to-locate winter star that is virtually on the celestial equator is Mintaka, or Delta Orionis — the right-hand star of Orion's belt. Third-magnitude Sadalmelik (Alpha Aquarii) is a summer star on the equator, but you could also use Altair (9° north of the equator) instead. Divide the number of minutes it takes for an equatorial star to drift across your finder's field by four to determine the finder's approximate field of view in degrees.

Many finders have 4° fields of view, as indicated by a star-drift time of about 16 minutes. If you know your finder's field of view, you can approximate the 0.7° distance between Polaris — the pole star — and the celestial pole itself. Some telescope manufacturers equip their finderscopes (or alignment scopes) with reticles that show the precise offset of the pole from Polaris.

At this point we know our finder's field of view and that the pole is 0.7° from the pole star, but we don't know which direction the pole is from Polaris. Fortunately, an imaginary line intersects both the pole and the pole star. The line runs from Eta Ursae Majoris, the star at the end of the Big Dipper's handle, through the celestial pole, through the pole star, and terminates at Epsilon Cassiopeiae, the northeasternmost star in the "W" of Cassiopeia. Remember that the pole is 0.7° from Polaris, in the direction of the Big Dipper.

The next step with a fork-mounted telescope is to turn the scope until the declination circle reads 90° and points in the direction of the pole star. Now turn the telescope in right ascension until the declination axis of the telescope is perpendicular to the imaginary dipper-pole-Polaris-Cassiopeia line in the sky. Site from the rear (south) end of the telescope tube. One of the finder's crosshairs should track along the imaginary line in the sky.

Next, with the telescope's right ascension and declination axes locked, move the scope's base or mounting in altitude and azimuth (i.e., up/down and right/left, respectively) until Polaris lies 0.7° from the center of the finder's field along the crosshairs tracking the imaginary line in the sky. Several telescope manufacturers equip their mountings with fine adjustments in elevation and azimuth. Polar aligning a telescope by shimming up tripod legs is enough to drive any astrophotographer to take up another hobby. I almost quit when I discovered that in order to align a telescope properly for the latitude of southeastern Arizona, I had to dig a hole for one of the legs of the tripod.


An 8-inch SCT rigged for piggyback photography is silhouetted against an evening sky.

When positioning Polaris in your finder, remember that most finderscopes invert the view. If Polaris appears to be to the right of the pole, it should actually lie 0.7° to the left of the center of the finder's field. This procedure sounds complicated, but with practice you will polar-align accurately enough for many purposes in less time than it takes to read about it.

Drift Method of Fine Polar Alignment

The finderscope alignment method just described is a reasonably precise way of ensuring that the optical axis of your telescope points toward the pole. We also want to align the mechanical axis of the scope. Beware — the optical mechanical axes of amateur telescopes do not always coincide. If they don't, the so-called "drift method" allows you to polar-align your telescope with considerably more precision. With this greater precision comes the benefits of fewer guiding corrections and easier location of target objects.

Use an illuminated-reticle guiding eyepiece in your telescope to point the scope at a star near the celestial equator and near the meridian. Orient the reticle's crosshairs so that moving the telescope's slow motion controls in right ascension (i.e., east or west) moves the star along a crosshair. Re-center the star in the eyepiece and let the telescope track for about five minutes.

If the star drifts north, your scope's polar axis is pointed too far to the west. Conversely, if the star drifts south, its polar axis is too far east. (Ignore drift in right ascension.) Finding north in the

ANTI-MURPHY RULES

In astrophotography, Murphy's Law ("If anything can go wrong it will") reigns supreme. It's almost as if your intelligence disintegrates the first time you use complicated equipment in the dark. As a stress-management technique I offer the rules listed below. I know them well:

- Make sure there is film in the camera.
- Squeeze off a few shots at the beginning of each roll in daylight so your film lab won't cut your dim astronomical negatives across the middle.
- Firmly secure the lens-plus-camera combination to the telescope.
- Center a bright star in both the camera's finder and in the scope's eyepiece.
- Take the lens cap off.
- Use a lens hood to prevent dewing and glare from stray lights.
- If necessary, periodically blow-dry the lens with a hair dryer.
- Focus the lens at infinity.
- Set the lens for the proper f/stop.
- Set the camera's shutter to "B" or "T."
- Hold the shutter open with a locking cable release.
- Wind the film.
- List object, time, date, sky conditions, and camera setting for each exposure.

This last step of keeping track of technical data is important to pinpointing your successes and errors. It also serves as a reminder of what works for you.

eyepiece at this point may be difficult. I usually cheat and nudge the telescope to the north by hand. If the crosshairs follow the star, then the star has been drifting north and your mount is pointing too far west. Adjust it eastward before you repeat the drift test. Repeat these steps until the drift is eliminated, or until you say "to hell with it." I usually repeat the test until I'm about halfway between these extremes. Don't get discouraged by clumsy first attempts at this alignment.

Next, point the telescope at a star near the equator and near the eastern horizon; center it in the reticle crosshairs as before. Again, let the scope track for five minutes or so. If the star drifts north in your eyepiece, the scope's polar axis is too high. If it drifts south, the axis is too low. Move the scope's axis in the required direction and repeat the procedure until the drift is eliminated. Now your scope should be precisely polar aligned.

Recheck the first test with a star at the meridian, just to be on the safe side. I found that keeping a written record of which way the star drifted and which corrective moves I used dramatically shortens the procedure and cuts down on the crashing around in the dark (during which time you forget which way the star drifted or which way you moved your mounting).

Drift-alignment can be time consuming, but I've found that unless I'm unusually clumsy, I can drift-align with time to spare between when the stars first appear and the end of astronomical twilight when I want to begin photography. If you can leave your scope assembled for any length of time, one drift alignment session should suffice for the whole period. Remember that this procedure — once practiced and written down — is much less complicated than it sounds. Alignment in astrophotography is so important that once done properly, the other steps seem easy.

A piggybacked camera caught this 20-minute exposure of Comet Hyakutake.

BEST TARGETS FOR PIGGYBACK ASTROPHOTOGRAPHY

The typical amateur telescope has a field of view of 1° or less. Long-focus 300mm or 400mm telephoto lenses allow for expanded field coverage. (See table in "Camera and Tripod Photography.") Use piggybacking to photograph objects whose angular size is too big to fit into your telescope's field of view. Large, worthwhile photographic targets abound. Here are a few of the finest for piggybacking:

NAME	CONSTELLATION	ANGULAR SIZE
Milky Way (summer)	Sagittarius	~30°
North America Nebula	Cygnus	~3°
Andromeda Galaxy (M31)	Andromeda	~3°
Orion	—	~20°
Orion's Belt and Sword	Orion	~7°
Lagoon and Trifid nebulae	Sagittarius	~2°
The Pleiades (M45)	Taurus	~2°
Antares region	Scorpius, Ophiuchus	~4°
Gamma Cygni region	Cygnus	~4°

Deep-color exposures of these celestial showpieces will inspire you to photograph others that are almost equally rewarding. Success with these targets will also tempt you to try close-ups of galaxies, nebulae, and star clusters, which can only be done by the more challenging method of through-the-telescope photography.

Guide the Exposure

Accurate polar-alignment and a short-focus wide-angle lens may allow piggyback exposures of up to an hour. Be aware that misaligned telescopes, high-magnification telephoto lenses, through-the-telescope imaging, irregular drive motors, wind, and atmospheric turbulence and refraction may require corrections during the exposure. Expect to guide every piggyback exposure with occasional corrections. Ease this task by inserting an illuminated reticle eyepiece, selecting a guide star, and orienting the crosshairs. During the exposure, use the telescope's slow-motion controls to keep the guide star on the illuminated crosshairs of the eyepiece.

Finally, don't forget to keep track of your exposure times with an illuminated stopwatch. Many computerized telescopes come with built-in timers. I don't have that luxury but instead use a primitive, low-tech alternative: a lowly kitchen timer. It ticks while counting down and dings when time's up, leaving my hands free. ◼

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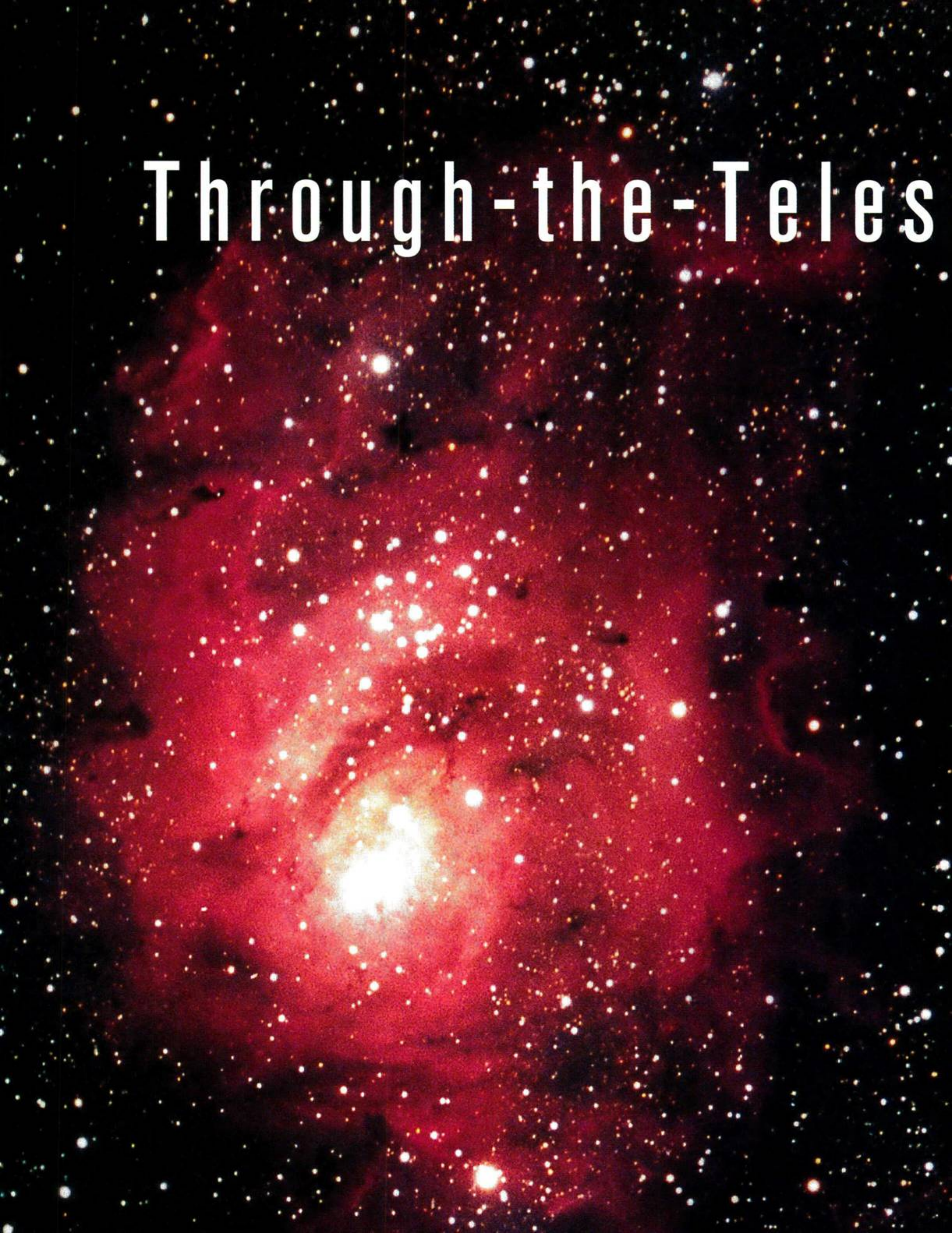

cope Photography

Focusing on those faint and fuzzy deep-sky splendors requires real astrophotographic know-how.

By David Healy

YOU'VE MASTERED THE BEGINNING elements of astrophotography, and now you want to step into the ring with the big boys. Nebulae, galaxies, and clusters have been taunting you, and you're ready to grab them and beat them into submission. With the right steps and equipment, you'll be able to produce a knockout deep-sky astrophotograph.

The most demanding method of amateur astrophotography is through-the-scope, or prime focus, photography. This method involves attaching a 35mm camera to the rear cell (i.e., prime focus) of a telescope, thereby turning it into a monster telephoto lens. For example, if you attach your camera to an 8-inch Schmidt-Cassegrain telescope with a focal ratio of 10, it becomes a 2032mm telephoto lens (80-inch focal length times 25.4 millimeters to the inch). If a "normal" 50mm camera lens is regarded as having a magnification of 1 (which means it has no magnification or reduction in the image it produces) and magnification increases proportionally to focal length, then the 8-inch SCT to which

The Lagoon Nebula, M8, as photographed through a 7-inch refractor. Michael Stecker

The Whirlpool Galaxy, M51, can only be photographed through a telescope. Tony and Daphne Hallas

you have attached your camera has a magnification of about 41 (i.e., 2032/50).

Taking deep-sky pictures at 41 power is sufficient to make "close-ups" of many of the galaxies, star clusters, and nebulae that are too small in angular diameter to show up well in piggyback photos, even those taken with long-focus lenses. However, every problem or mistake that occurs over the course of a long exposure is also blown up by 41 times: Every gust of wind that shakes the telescope, every minor focusing error, and every tracking and guiding error, human or mechanical, will be obvious on your photo. To these potential problems you can add the simple challenges of finding the object you want to photograph and locating a suitable guide star. For no matter how fine your polar alignment and telescope drive, exposures long enough to record any deep-sky object on film must receive guiding corrections during the exposure. Whether these corrections are made by you or by an autoguider is a subject we'll get into later.

The Tools of the Trade

Let's start at the beginning. What equipment will we need for prime-focus astrophotography? The list will include all the items we used for piggybacking (see page 94) plus a couple other essential gadgets. The following seven or eight items will help you take that top-prize photo.

First, use an equatorially mounted telescope on a tripod or pier. My photography has been done with fork-mounted Schmidt-Cassegrain telescopes, but the techniques should be similar with German equatorials, etc. Unfortunately, because of the field rotation problem discussed in the piggybacking article, altazimuth-mounted scopes are inappropriate for long-exposure prime-focus photography unless equipped with a field de-rotator. The scope should be painstakingly polar-aligned.

Second, get an adapter to attach the camera body to the telescope. Telescope makers such as Meade and Celestron offer T-rings and T-adapters to fit their telescopes to various camera brands, and Orion Telescopes and Binoculars has a wide selection.

Third, an illuminated-reticle guiding eyepiece will be very useful. Again, many telescope makers offer these. Typically they are 12mm focal-length eyepieces with double crosshairs and variable-brightness LED illumination powered either by a self-contained battery pack or a cord that plugs into a power source in the telescope base. I strongly recommend the battery-pack model because there is less to trip over in the dark.

Fourth, obtain a 35mm camera body. Preferably this should be an "obsolete," mechanically operated model, whose shutter can be held open with a locking cable release. Ideally, the camera should be equipped with a bright focusing screen that will enable you to see dim target objects in the camera finder and focus accurately on a star. (Orion offers these screens, which require a Pentax, Olympus, or Nikon camera model with screen-interchangeability). An accessory right-angle finder will reduce the contortions necessary to set up a long-exposure deep-sky photo and probably enable you to shoot some inconveniently located objects that you would be unable to otherwise.

A fifth element for good through-the-telescope astrophotography is anti-dew protection, especially for front-lens telescopes such as SCTs, Maksutovs, or refractors. Dew protection will have to be more or less automatic if you are planning to guide your photos manually. The best dew protection is to shoot your photos from a dry-climate location. Failing that, a friend manning a hair dryer is next best. Sometimes a simple lens hood will suffice, unless the object being photographed is near the zenith. Orion and Kendrick Astro Instruments offer lines of electrically heated dewcaps and straps that cure dewing problems on all but the wettest nights. Kendrick also offers batteries that will power the anti-dew heaters (and your telescope drive) in the field.

An off-axis guider is sixth on our list. This guider, positioned between the rear cell of the telescope and the camera, has a small prism that protrudes slightly into the edge of the camera's field of view. Its purpose is to pluck the image of a star from the edge of the field and divert it into a tube containing the guiding eyepiece. Off-axis guiders have the advantage of stability — guiding corrections can be made from the field of view that is being photographed. The main disadvantage of an off-axis guider is that appropriately positioned guide stars may be hard to find. What's more, guide stars are dimmed because only a small portion of the telescope's incoming light path (i.e., that which falls on the guider's prism) is used to image the guide star. Your ability to find an appropriate guide star may depend on what you're photographing. If you are shooting a nebula or star cluster embedded in the Milky Way, guide stars will be plentiful. On the other hand, you may struggle to find a guide star if you are photographing galaxies, which are usually found in star-poor regions of the sky. Several suppliers offer off-

THE ST-4

Santa Barbara Instruments Group offers a fairly primitive CCD camera called the ST-4. This camera has such a tiny imaging chip that most amateurs have abandoned it in favor of SBIG cameras with larger imaging areas and advanced features. But the ST-4 can be used as an automatic guider in place of the guiding eyepiece when inserted in the eyepiece holder of the off-axis guider or guidescope. The ST-4 has its own control box and does not need to be operated from a computer if it is used as an autoguider. Once a guide star is centered in the eyepiece, the ST-4 is substituted for the eyepiece, positioned for proper focus and orientation, and set to begin sending guide corrections to the telescope. I have used it to make guided exposures as long as two hours. SBIG has just introduced the STV CCD camera, a major upgrade of the ST-4, offering increased sensitivity, a built-in LCD monitor, and compatibility with video monitors and VCRs. The usual cost-versus-capability tradeoff applies.

axis guiders, including Meade, Celestron, Orion, and Lumicon.

Alternatively, you can use a separate guidescope. Guide telescopes, which are mounted on the telescope being used for photography, have the advantage of easy guide-star selection. Guidescope mountings can be moved left/right and up/down in relation to the main telescope, allowing you to guide the photograph using any nearby bright star, which can be located by using the guidescope's finder. The primary disadvantage of a guidescope, aside from the additional weight that might unbalance the main telescope, is that over the course of a long exposure the guidescope may flex in relation to the main scope, causing tracking errors on the film. Small-aperture long-focus refracting telescopes as well as 3½-inch to 5-inch SCTs can be turned into appropriate guidescopes. Guide Star offers a selection of adjustable mountings for various popular telescopes and guidescopes.

And lastly, consider a telecompressor, or focal-reducing lens. Many popular telescopes have such long focal ratios (f/10 or greater) that photographing dim deep-sky targets such as galaxies requires impractically long exposure times. The telecompressor threads into the off-axis guider body or into the camera-to-telescope adapter and effectively reduces the focal ratio of the optical system, typically by two stops, from f/10 to f/5. This reduction has several consequences, among them that exposure times can be reduced by 75 percent (or even more, depending on the reciprocity characteristics of the film you are using). The field you are photographing is, accordingly, reduced to 25 percent of its original area, a considerable sacrifice in image scale, but one that can be minimized if you can use a fine-grain film. Your photograph will now likely display vignetting — your galaxy will look as if it is being viewed through a porthole. This effect can be eliminated during image processing or enlarging by cropping the image. The usual suspects — Meade, Celestron, Orion, and Lumicon — supply telecompressors.

Locating Deep-Sky Objects

All the targets in the accompanying table are bright enough to be seen in the typical telescope's finder if the sky is not too light polluted. However, it is advisable to learn the use of your telescope's pointing tools (digital or manual setting circles or "go-to" capability) and the target's celestial coordinates (right ascension and declination) to reliably find these and other dimmer objects. Facility in this sort of celestial navigation will be invaluable in photographing such objects as the Horsehead Nebula, which you are unlikely to be able to see at all in your finderscope or camera viewfinder.

An indispensable guide not only to finding deep-sky objects and their angular size and brightness but to every aspect of amateur astronomy is the annual *Observer's Handbook*. The year 2000 edition of this must-have book is available from the Royal Astronomical Society of Canada, 136 Dupont Street, Toronto, Ontario, Canada M5R 1V2.

Assuming that your telescope is accurately polar-aligned, a reliable way of locating deep-sky objects is to offset from a nearby bright star. It's sort of a numerical star-hop method. For example, if you want to locate M57, the Ring Nebula, you can point your telescope at Vega, which, according to the *Observer's Handbook*, is located at 18h37m right ascension and 38°47' declination. If your telescope has manual setting circles, set them to Vega's coordinates. If your telescope has digital setting circles or "go-to" capability, "synch" on Vega. Again, according to the *Observer's Handbook*, the Ring's coordinates are 18h57m right ascension and 33°2' declination. With manual setting circles, move your telescope until the circles read the Ring's coordinates. If you can't see it in the eyepiece or camera finder, a little sweeping should pick it up. If you are equipped with "go-to" capability, then "go-to" M57.

Get Ready, Get Set . . .

Once you have your guide star in the field of view, make sure that Vega is sharply focused in the camera finder. You will discover that focusing your camera using the deep-sky object you want to photograph is highly unreliable — after all, nebulae are by definition fuzzy. Always focus on a nearby bright star, traveling through and beyond sharpest focus several times to be certain. While your telscope-plus-camera-plus-guider-plus-reticle-eyepiece rig is pointed at Vega, take the opportunity to move the star around and just outside your camera's field of view (using the scope's slow-motion controls). Do this to learn at what position relative to your camera's field of view Vega can be seen in the guiding eyepiece. I habitually rotate the guider body relative to the camera so that a star just off the left margin of the camera's finder can be seen in the guiding eyepiece. With that position in mind, it will be much easier to locate a potential guide star using the camera's finder. Then move the telescope until that star is just off the left edge of the camera's field. With a little luck, you can find such a star with your target object still more or less centered in the camera's viewfinder. Take this opportunity to focus Vega in the guiding eyepiece, but not by using the telescope's focuser, for this will throw Vega out of focus in your telescope and camera. Focus the star image in your guiding eyepiece by sliding the eyepiece in and out of its tube.

Now move the telescope back to M57

Through-the-telescope photography allows you to image deep-sky objects. *Astronomy* and locate a guide star. If it is necessary to rotate the camera and guider to position the guide star so that it can be seen in the guiding eyepiece, it is best to return the telescope to Vega and refocus, for rotating the guider or camera may have defocused the image. One further note on focusing: make it a practice to refocus after every exposure. Focusing with these extremely long focal lengths is so sensitive that even the cooling-off of your telescope in the evening will shorten its focal length and throw your picture out of focus.

Guiding Light

Once the camera is focused and returned to M57, turn the guiding eyepiece in its tube until the guide star will track along one of the illuminated crosshairs when the telescope is moved in right ascension (east/west). This position of the guiding eyepiece will vastly simplify making guiding corrections later on. Center the guide star in the crosshairs, start your timer, and begin the exposure by opening the shutter with a locking cable release. Using your telescope's "guide" speed slow-motion controls or a separate drive corrector, keep the star at the intersection of the crosshairs during the exposure. If the star tends to drift out of its proper position to the east or west, the cause is most likely to be irregularities in your telescope's drive gears. Most telescopes suffer from some degree of "periodic error" that recurs over the time that it takes the worm gear to make one revolution — a period of perhaps four minutes. Some of the newer amateur scopes have "periodic error correction" (PEC) in which the scope's electronics actually "learn" the gears' periodic error and automatically compensate by speeding or slowing the drive rate at the proper times. A PEC system, when properly programmed, can sharply reduce the number of guiding corrections needed.

If the guide star consistently drifts either north or south during the exposure and requires corrections in declination, the culprit is probably poor polar alignment.

Manual guiding is fun for about the first five minutes but can be a major drag over the course of a long exposure, especially if you haven't properly anticipated which way the scope will move during the exposure and you find yourself in an excruciatingly cramped position. Some faint objects (or slow films) can require exposure times of an hour or more. The task of guiding exposures this long is a test of human endurance (or at least bladder capacity) and calls into question the notion that astronomy is something we do for the love of it.

SELECTING TARGETS FOR DEEP-SKY PHOTOGRAPHY

The table below lists a dozen showpiece deep-sky objects that are worthy candidates for photography. The are all relatively bright, easy enough to find in the sky from midnorthern latitudes at different times of the year, and offer a relatively high reward-to-effort ratio. We have selected two or three examples of various kinds of objects, ranging from open and globular star clusters to planetary nebulae to supernova remnants and galaxies. We also suggest some trial exposure time for PJ 400 (color negative) film and an f/5.6 optical system. Two images taken with the through-the-telescope method are on page 100 (Lagoon Nebula, M8) and page 102 (Whirlpool Galaxy, M51).

Target @ f/5.6	Type	Constellation	Trial Season	Exp. Time
M42 (Orion Nebula)	Emission Nebula	Orion	Winter	15 minutes
M8 (Lagoon Nebula)	Emission Nebula	Sagittarius	Summer	25 minutes
M45 (The Pleiades)	Open Star Cluster & Reflection Nebula	Taurus	Winter	35 minutes
M57 (Ring Nebula)	Planetary Nebula	Lyra	Summer	20 minutes
M27 (Dumbbell Nebula)	Planetary Nebula	Vulpecula	Summer	25 minutes
M37	Open Star Cluster	Auriga	Winter	15 minutes
M46	Open Star Cluster & Planetary Nebula	Puppis	Winter	25 minutes
M51 (Whirlpool Galaxy)	Spiral Galaxy	Canes Venatici	Spring	35 minutes
NGC 4565	Edge-on Galaxy	Coma Berenices	Spring	35 minutes
M13 (Hercules Cluster)	Globular Star Cluster	Hercules	Summer	15 minutes
M23	Globular Star Cluster	Sagittarius	Summer	20 minutes
M15	Globular Star Cluster	Pegasus	Autumn	20 minutes

The Finishing Touch

Most photo labs do a satisfactory job developing astronomical slides and negatives. Where they often come up short, however, is in making prints and enlargements, with color balance and density of sky backgrounds the most common problems. I have sent back many 8" by 10" enlargements for a remake to cure bright-green skies or purple stars. The best tactic is to use one photo lab consistently and "train" it to print your enlargements with a proper color balance. I have found that the instructions "print for a neutral dark-gray sky background" can work wonders.

One alternative to having a commercial photo lab make your enlargements is to have them made by an astronomer who understands the quirks of sky photography. Longtime astrophotographers Tony and Daphne Hallas offer a photo lab service that will make enlargements from your negatives and slides.

Probably the most fascinating development in film astrophotography in recent years is the precipitous drop in the prices of digital film scanners and color printers capable of turning out photo-quality enlargements. This price drop has made complete digital imaging capabilities available for about the price of one of Al Nagler's better eyepieces and threatens to put amateur astronomers out of the darkroom for good. Although I use a Hewlett Packard Photo Smart scanner, Epson and Canon color printers, and Adobe Photoshop image processing software, photographers can choose from a wide selection of highly capable scanners, printers, and software that continues to drop in price and increase in power. Even apart from any "retouching," you can digitally correct the color balance and contrast of your negatives and slides, remove dust and scratches, and print them on glossy photographic paper or e-mail them to your friends. If amateur astrophotography with film has a promising future, and I believe it has, it is in large part due to the digital revolution that is making conventional picture-making obsolete.

David Healy wrote all four of the astrophotograph articles in this issue and practices the hobby from his home in Arizona.

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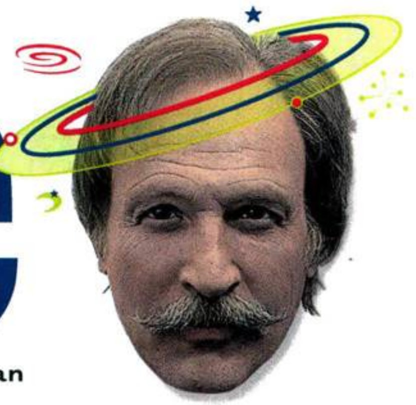

By Bob Berman

Bubbleland

We need a new branch of astronomy. We've got solar science, cosmology, spectroscopy, photometry. We've got optics, planetary studies, lots of categories. But we need a new one. Let's call it . . .

Bubbleland.

Bubbleland is for things totally outside our understanding, places where we now provide the public with technical-sounding vacuity. For example, what existed before the Big Bang? I get that question a lot from students, and I'll admit to being guilty of reciting the standard speech. "The Big Bang," I explain grandly, "created time as well as space. Since there was no time or space before the Big Bang, your question is meaningless."

The student is silenced. The class continues. The professor obviously knows something wonderfully profound. But I can't do it anymore. The next time someone asks, I'll tell the truth:

"Nobody has the foggiest idea what happened the Tuesday before the Big Bang. Who can say whether there was a previous collapsing universe or an incipient quantum fluctuation. That whole domain is part of Bubbleland."

Bubbleland. The realm beyond the present reach of science.

Then the class will nod and really understand. Ah, yes, we've arrived at Bubbleland. The realm beyond the present reach of science.

Anyone attending a cosmology lecture can tell when the speaker arrives at Bubbleland. "It's not galaxy clusters that travel outward," he'll say pedantically, "but space itself that grows larger. The galaxies don't actually move."

So here I am thinking, wait a minute. Are we at a Daffy Duck convention? Is this guy saying that empty space, nothingness, a vacuum, is capable of growing like a petunia, independently of the universe's mass and energy? If so, then suppose nothingness alone existed (a contradiction in itself). If there were no galaxies, atoms, or even light in the universe, just space, could you still claim that the emptiness was getting bigger? What could that mean? And if you do critically need galaxy groups to define the increasing emptiness between them, why then insist they are not part of the process? (Actually, some relativity experts, such as David Nightingale, co-author of *A Short Course on General Relativity*, are even uncomfortable with our exclusion of "local space" from the universe's expansion.)

Or take singularities at the hearts of black holes. When explaining what happens to a massive collapsing star, physicists usually say that it achieves infinite density and zero dimension. When I've laid that on students, the funny thing is, they buy it. No one rolls his or her eyes. My fantasy is to witness the following scene at a large lecture hall. First, the professor didactically informs his students that a collapsing star achieves infinite density and no volume. Then, suddenly, all 150 students silently rise and simultaneously make the "c'mon now" hand gesture.

Reality check: Nothing can be infinitely dense, except our gullibility, as when we imagine that a politician said something substantive. And "zero volume" has no place in this universe, except as wishful thinking when confronting a teenager's stereo.

Obviously, a process beyond our present understanding must happen with singularities. Perhaps other dimensions come into play, in which case the collapsed star deserts our reality altogether. In truth, we have no clue. We should say we have no clue. But since there is no official category for what happens to singularities, we'll just say they enter Bubbleland and everyone will understand.

Quantum mechanics has Bubbleland reserved practically for itself. You do the standard experiment and fire electrons or photons through slits onto a background screen and get the classic interference pattern that proves these items are waves, or at least act that way this afternoon. Now the spooky part. Fire just a single electron at a time at the screen. Still you get the interference pattern. The electron is interfering with others.

There is no official category for what happens to singularities.

Problem: There are no others. Only one electron is in the device at a time. With what is it interfering?

Nobody has ever answered this. It defies common sense. This and many other quantum effects (such as when particles are in "superposition," or when they inexplicably randomize as if to deliberately hide information from us, or when they "entangle" with a distant particle so the act of measuring one instantaneously affects the other) demonstrate that conventional thinking sometimes fails on the subatomic level. Our brains evolved to deal with mortgages and bacon cheeseburgers, not electrons. Common sense is apparently the wrong tool — a little like trying to use a screwdriver to tighten a nut. Quantum effects are experimentally repeatable, so they do possess their own logic, but it makes many of us multicellular observers uncomfortable. We're left with a simple shrug: This is just how the tiny kingdom works.

Recently a few maverick physicists have come right out and admitted that the interference-when-there's-nothing-there business must be confronted. They've suggested that perhaps numerous neighbor dimensions exist, alternate realities that lurk so closely next door, perhaps just a hair out of "phase" with our own, that our electrons interfere just enough with theirs to produce these strange interactive patterns. Yes, that is probably wacky and undoutably wrong. But it's good that some are dealing imaginatively with quantum weirdness.

We could go on and on. The late Carl Sagan, whom I love and admire, nonetheless said, "Now that we've explained how life began, there's no place for God." Well, let's leave religious belief out of this and just address science's explanation of life's genesis. The prevailing account posits a mixing of organic molecules, the arrival of amino acids on comets from space, some accidental combinations, and then comes the great denouement: "and somehow life arose."

Beep! Hold it! That "somehow" may be only one little word embedded among the thousands making up the "explanation," but it changes the whole thing to: "We haven't a clue." How consciousness or self-awareness can arise from amino acids remains as deep a mystery as it ever was. But since we do not want our experts to stand mute and nonplussed, we have now supplied an out. They do not have to utter the dreaded "I don't know."

Finally they can explain our origins. **We come from Bubbleland.** 🅰

Bob Berman, who writes frequently for Astronomy, *will provide us with "Strange Universe," a regular column.*

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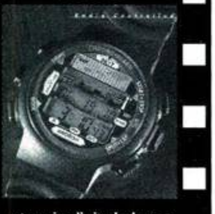

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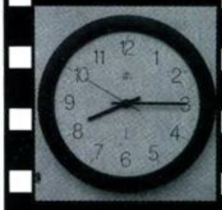

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BOOKS

The Accelerating Universe: Infinite Expansion, the Cosmological Constant, and the Beauty of the Cosmos

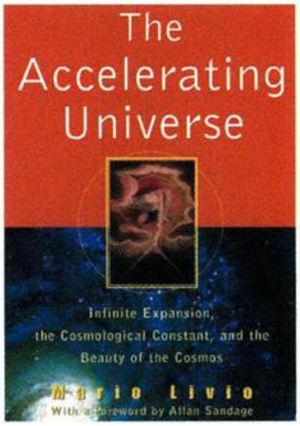
▶ Mario Livio, 288 pages, John Wiley and Sons, New York, 2000; ISBN 0-471-32969-X; hardcover, $27.95.

The Runaway Universe: The Race to Discover the Future of the Cosmos

▶ Donald Goldsmith, Perseus Books, Cambridge, Mass., 2000; ISBN 0-7382-0068-9; hardcover, $25.

In 1929, Edwin Hubble changed the course of cosmology when he announced evidence suggesting that the universe is expanding. While Hubble himself remained skeptical of cosmic expansion until his death, astronomers today accept expansion as fact and now concern themselves with a deeper question: What is the fate of our universe? Will it expand forever, or will gravity one day reverse the process, resulting in a Big Crunch? This question is the subject of two new books: *The Accelerating Universe* by Mario Livio and *The Runaway Universe* by Donald Goldsmith.

The answer to this question may be at hand. Two astronomy research groups recently announced that the universe will continue to expand forever, and even more incredibly, the expansion is accelerating. Their conclusion is based on painstaking observations of extremely distant supernovae — located in galaxies billions of light-years away. The two teams found that the most distant supernovae are much dimmer than they should be based on standard cosmological models. The interpretation is that these supernovae appear fainter (and are therefore more distant) because cosmic expansion is accelerating.


The Accelerating Universe
Infinite Expansion, the Cosmological Constant, and the Beauty of the Cosmos
Mario Livio
With a Foreword by Allan Sandage

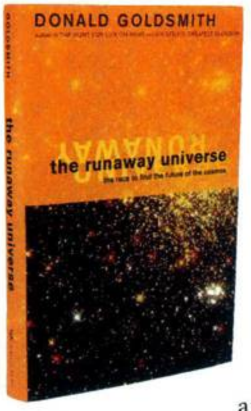
In *The Runaway Universe*, Goldsmith tells us the story of these competing teams and their race to discover the ultimate fate of the universe. Goldsmith first explains Einstein's cosmological constant and how its numerical value affects cosmic acceleration and the ultimate fate of the universe. He moves on to Edwin Hubble's discoveries of galaxies and the expanding universe. Goldsmith later explains how dark matter dominates the universe and how its gravitational effects hold the key to the fate of the universe. This background information sets the stage for the story of how two teams used supernovae to reveal that our universe will apparently continue to expand forever at an ever-increasing rate.

Once Goldsmith makes the case for an accelerating universe, he asks if the result could be wrong and explains some potential sources of error that might nullify the case for an accelerating universe. Dust, for example, could make distant supernovae appear dimmer. Alternatively, the properties of very distant (and therefore very old) supernovae could be different from their nearby counterparts. He concludes the work with a discussion of the physical nature of Einstein's cosmological constant and the prospects for resolving cosmic conundrums.

In *The Accelerating Universe*, Livio discusses the new cosmology results as well. But his book has a much broader purpose. He explicitly states that the main theme of the book is to demonstrate the "beauty (or absence thereof) of physical theories." Livio spends the first few chapters discussing definitions of beauty and aesthetics and relating the basic tenets of physics to these concepts. He tells the story of cosmology starting from Hubble's observation of expansion and works in deeper theoretical aspects of cosmology.

The breadth of subjects Livio covers is impressive. In addition to cosmology, he discusses stellar evolution, the origin of life on Earth, searches for extrasolar planets and extraterrestrial life, and the anthropic principle. Be forewarned that some of the discussions are quite technical and may require more than one reading. *The Accelerating Universe* is interesting and unique, but Livio's occasional lengthy digressions into the symbolism of artistic or literary works may be distracting to some readers. In the end, he shows that physics and cosmology are beautiful and that science is as much a humanistic endeavor as any form of art.

The authors' different backgrounds lead to their respective approaches. Livio, a theoretical astrophysicist at the Space Telescope Science Institute, gives an insider's perspective. While his overall style is authoritative and philosophical, he transmits a genuine enthusiasm for both science and art and is often quite humorous. Goldsmith, an astrophysicist by training and a science writer by trade, narrates an exciting, fast-paced story that is more reminiscent of a television documentary. He gives just enough background to hook the reader and then plunges into an exciting story of cutting-edge astronomical research. Livio's book should appeal to those who enjoy philosophical adventures and want the cosmological big picture. Goldsmith's book is geared toward those interested in understanding the latest developments in cosmology without a lot of accessories. — *Jennifer Birriel, University of Pittsburgh* ■



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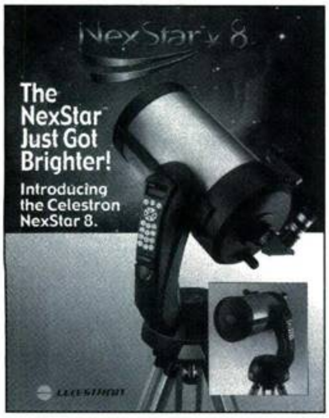
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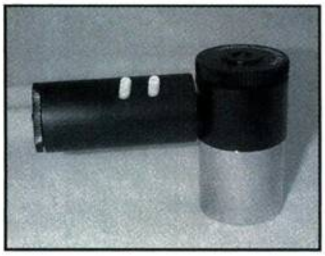

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See the Meade ad in this magazine for full descriptions. Starfinders are complete telescope systems with motor drive and finderscope (Equatorial only) and 25mm (48x) eyepiece. New DC motor runs on four AA batteries.

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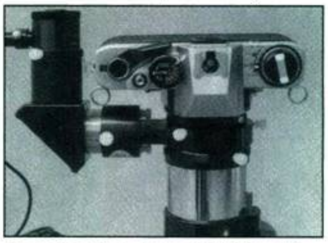

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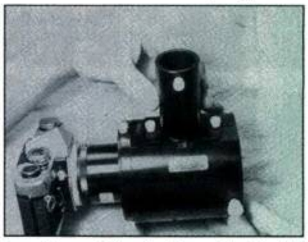

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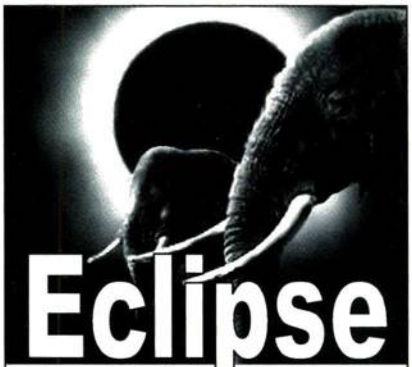

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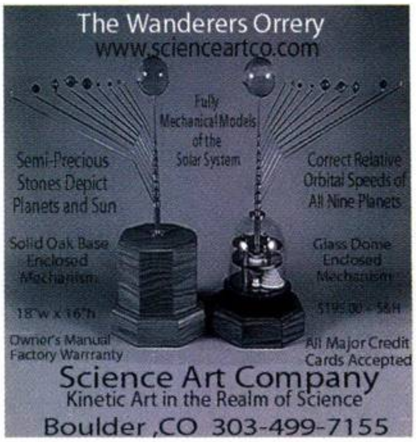

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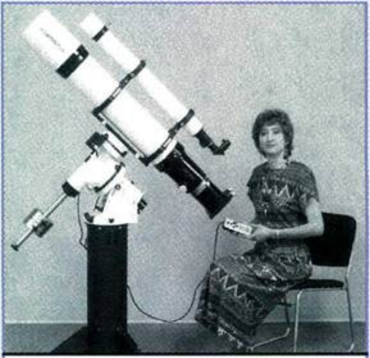

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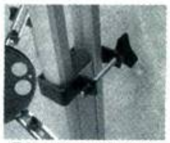

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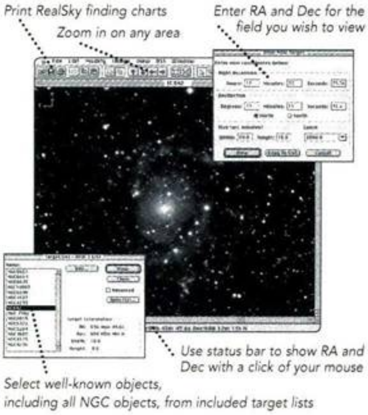
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MARS RETURNS TO CENTER STAGE

Although some Mars missions have failed, Global Surveyor has imaged the polar caps in great detail and discovered channels buried beneath the surface.

SUMMER'S BRIGHT COMET

Although it's still too early to know for sure, Comet LINEAR looks like it could be the hit of the summer observing season.

JUST SIX NUMBERS

Britain's Astronomer Royal takes a look at how a few simple numbers determine how our universe expands, whether stars and planets are able to form, and even if life can evolve.

TALE OF THE SCORPION

Awash with dozens of bright clusters and a smattering of nebulae, Scorpius stands out as a Milky Way treasure.

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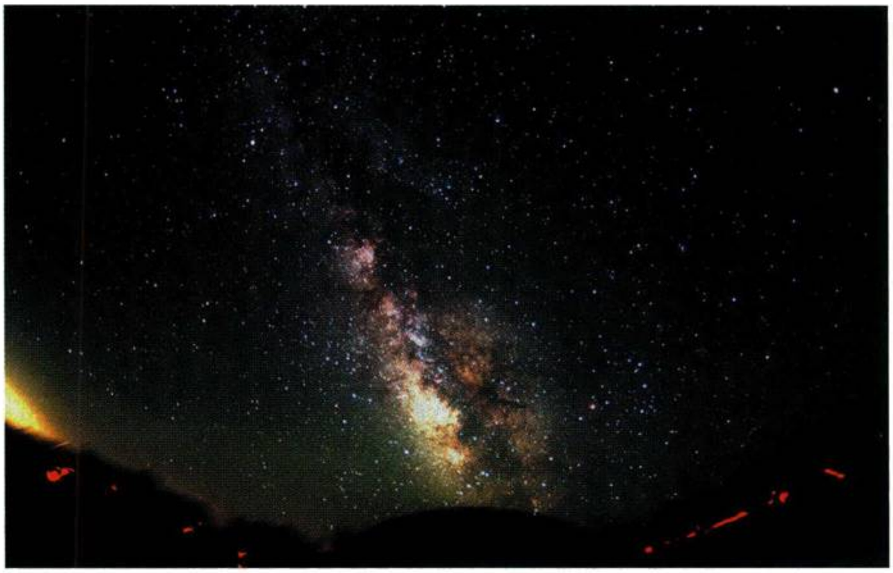
WOW: It's pretty cool when your event's initials describe one of the highlights of the year for Wisconsin area amateur astronomers. The **Northeast Wisconsin Stargazers** club is sponsoring WOW (Wisconsin Observers Weekend) **June 2–4**. Join them for summer camping and observing at Hartman Creek State Park, just west of Waupaca, Wisconsin. For more information, contact Terry Becker, 514 Union Avenue, Apt. E, Oshkosh, WI 54901; (920) 426-2286; e-mail, tlb@vbe.com; website, http://www.frontiernet.net/~celstar/wow.html.

Farther south on that same weekend (**June 2–4**), Devil's Den State Park is the site of the **Arkansas-Oklahoma Astronomical Society's June Star Party**. This year's theme focuses on basic astronomy, including selection, set up, and use of equipment. Contact Joe Roam, P.O. Box 31, Fort Smith, AR 72902; (501) 474-4740; e-mail, daleh@interserv.com; website, http://www.aoas.org.

Even farther south, the Tucson Amateur Astronomy Society invites the public to its 10th Annual **Grand Canyon Star Party**. This free event runs from **June 3–10** and features daytime tours and solar observing. Nighttime activities include enthusiastic stargazers who can't wait to share sky sights with others. Contact Dean Ketelsen, 1122 East Greenlee Pl., Tucson, AZ 85719, (520) 293-2855; e-mail, ketelsen@as.arizona.edu; website, http://www.tucson-astronomy.org.


Thomas Cooper

Summertime offers the opportunity to view incredible dark-sky sights, like this brilliant Milky Way expanding over a Colorado star party.

JUNE

Astronomy Camps

Mount Lemmon and Mount Bigelow Observatories, University of Arizona, Tucson, Arizona. **June 6–13**, beginning teenagers; **June 19–27**, advanced teenagers; **June 29–July 2**, educators. Contact Don McCarthy, 933 N. Cherry Ave., Tucson, AZ 85721; (520) 621-4079, e-mail, dmccarthy@as.arizona.edu; website, http://ethel.as.arizona.edu/astro_camp.

JUNE 1–4

Laurel Highlands Star Cruise

Tall Oaks Campground in Farmington, Fayette County, in southwestern Pennsylvania. Contact Terry or JoAnne Trees, 374 Vernon Street, New Kensington, PA 15068; (724) 337-3231; e-mail, Wayne or Mari Jo Meyers, mwm@bellatlantic.net; website, http://members.aol.com/lhstarcruise.

JUNE 2–4

Sky Tour 2000

Bellevue, Ohio, area. For information, write Tech2000, 69 South Ridge Street, Monroeville, OH 44847; (419) 465-2997; e-mail, tddi@accnorwalk.com; website, www.accnorwalk.com/~tddi/tech2000/.

JUNE 2–4

Jersey StarQuest

Hope Conference and Renewal Center, Hope, New Jersey. Registration deadline, May 17. For more information, contact Greg Mauro, 915 Princess Drive, Yardley, PA 19067; e-mail, k3ea@arri.net.

JUNE 4–8

American Astronomical Society (AAS) Meeting

Riverside Convention Center, Rochester, New York. Direct correspondence to: AAS 196th Meeting, American Astronomical Society, 2000 Florida Ave., NW, Suite 400, Washington, D.C. 20009-1231; (202) 328-2010; e-mail, aas@aas.org; website, http://www.aas.org.

JUNE 9–10

Apollo Rendezvous and Telescope Fair

Presented by the Miami Valley Astronomical Society at the Boonshoft Museum of Discovery, Dayton, Ohio. Astronaut Story Musgrave among the featured speakers. For more information, contact Pat Sisson, (937) 254-7950; e-mail, AR2000@mvas.org; website, http://www.mvas.org/index.html; or http://www.mvas.org/AR2000.html.

JUNE 9–11

50th Anniversary Convention of the Mid-States Region of the Astronomical League of Missouri

Avila College in Kansas City, Missouri. Contact Keith Green, 522 Second St., Belton, MO 64012; (816) 318-0514; e-mail, keithkc@swbell.net; website, http://www.sky.net/~martinez/msr.html.

JUNE 10

Hurricane Ridge Star Party

Olympic National Park, Port Angeles, Washington. Hosted by the Port Angeles High School Astronomy Club. Contact John Gallagher, (360) 417-5191; e-mail, jgalla@orca.esd114.wednet.edu.

JUNE 23–24

Craters of the Moon Star Party

Craters of the Moon National Monument, between Arco and Carey, Idaho. Sponsored by the Magic Valley and Idaho Falls Astronomical Societies. Contact Jay Sneddon, (208) 736-2447; e-mail, jsneddon@yahoo.com or Mark Brandon, (208) 357-3540; e-mail, skygaz@srv.net; website, http://members.tripod.com/mvas/craters.html.

JUNE 23–25

Mason-Dixon Star Party

Spring Valley County Park, near York, Pennsylvania. Sponsored by York County Astronomical Society and the York County Parks. Contact Jeri Jones, (717) 840-7226; e-mail, JLJ276@aol.com, or visit the website, http://home1.gte.net/dmdewey/mdsp.html.

JUNE 23–25

Fieldstar 2000

Ham Radio Field Day and Star Party. For more information, contact Vernonia Peak Observatory, 55371 McDonald Road, Vernonia, OR 97064; (503) 429-2430; e-mail, smikalow@vernonia.com.

JUNE 24–JULY 1

Southern Skies Star Party

Inca Utama Hotel, Lake Titicaca, Bolivia. For information, visit http://www.icstars.com/HTML/Bolivia/bolivia.html or contact Vic Winter, (913) 432-4636; e-mail, SSSP@icstars.com.

JUNE 30–JULY 2

GA 2000: The Millennium Assembly

Sponsored by the Royal Astronomical Society of Canada in Winnipeg, Manitoba. The RASC meeting with speakers and demonstrations is rounded out with a banquet and family activities. Winnipeg's Canada Day Celebration wraps up the event. Contact: Stan Runge, 35 Cunard Place, Winnipeg, Manitoba, R3T 5M1; e-mail, stan.runge@mts.mb.ca; website, http://www.rasc.ca/ga2000/. A

CONTACT

Please submit club announcements four months in advance to Looking Ahead, *Astronomy*, P.O. Box 1612, Waukesha, WI 53187, or to cryback@astronomy.com. Look for additional events at http://www.astronomy.com.

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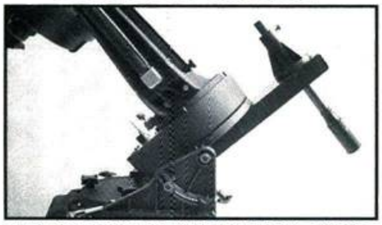

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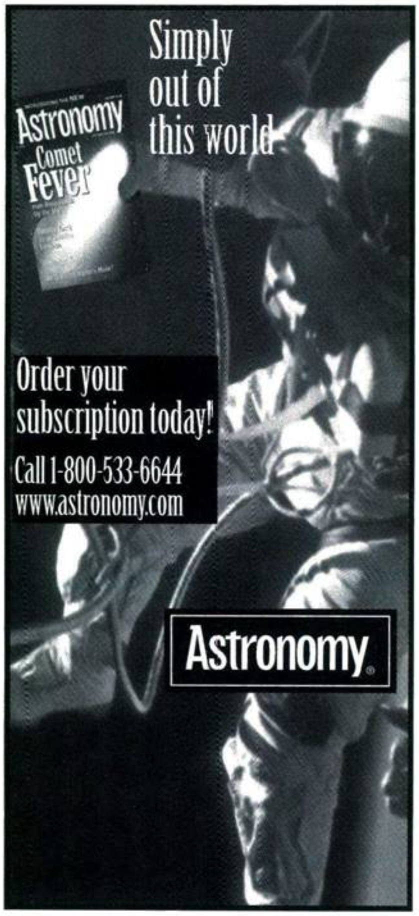

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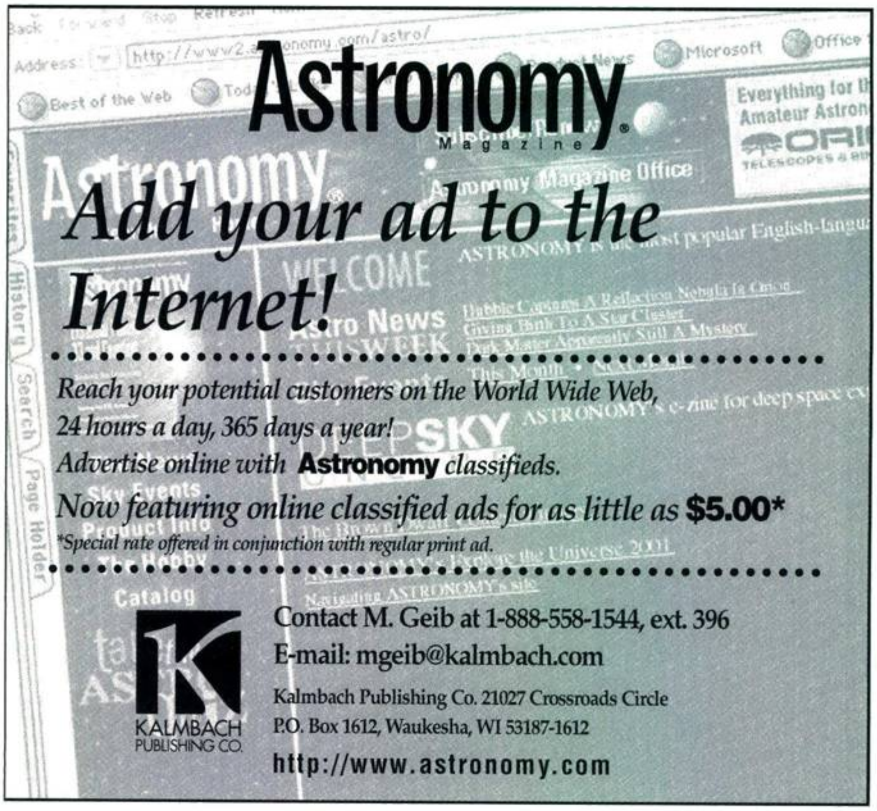

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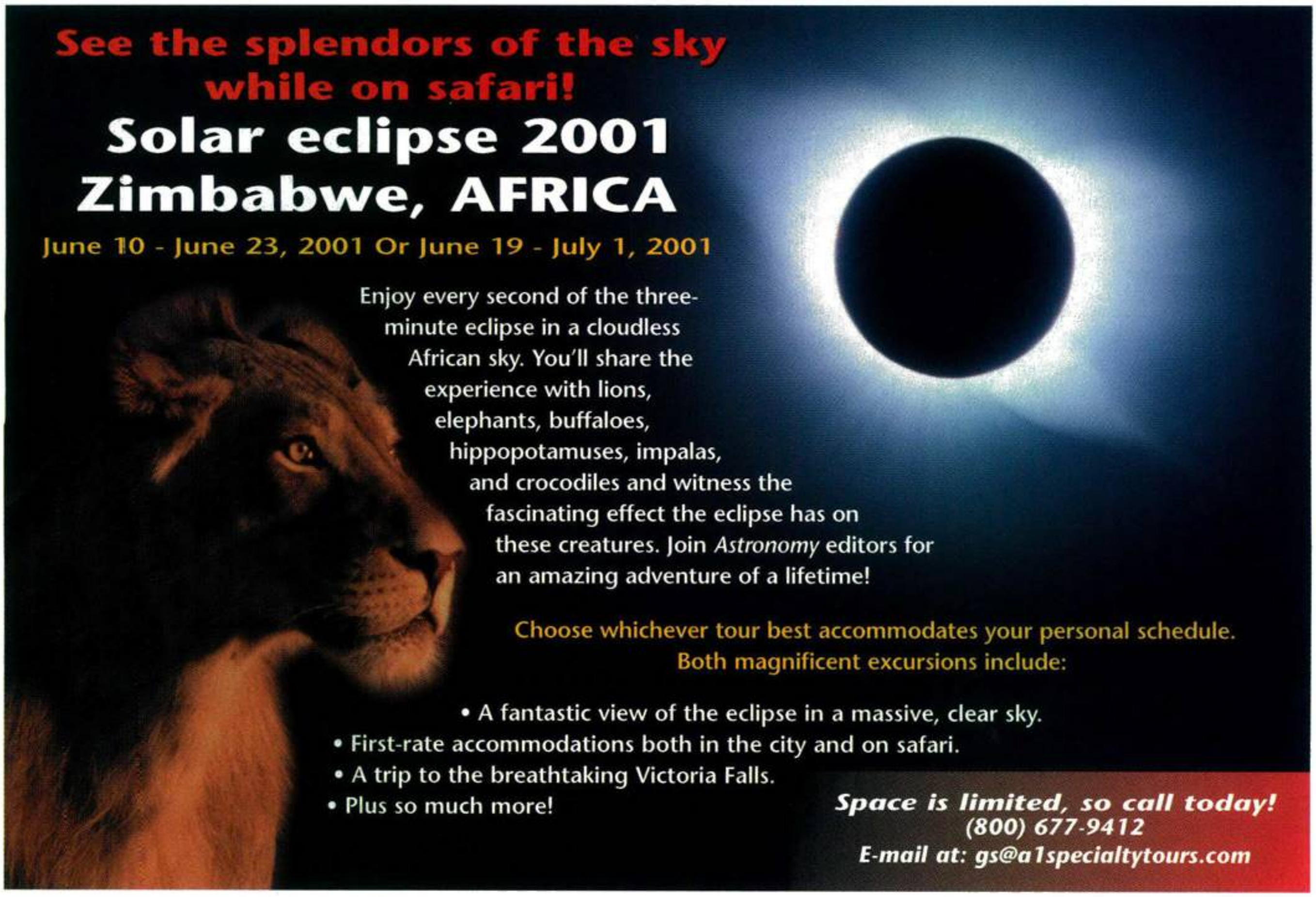

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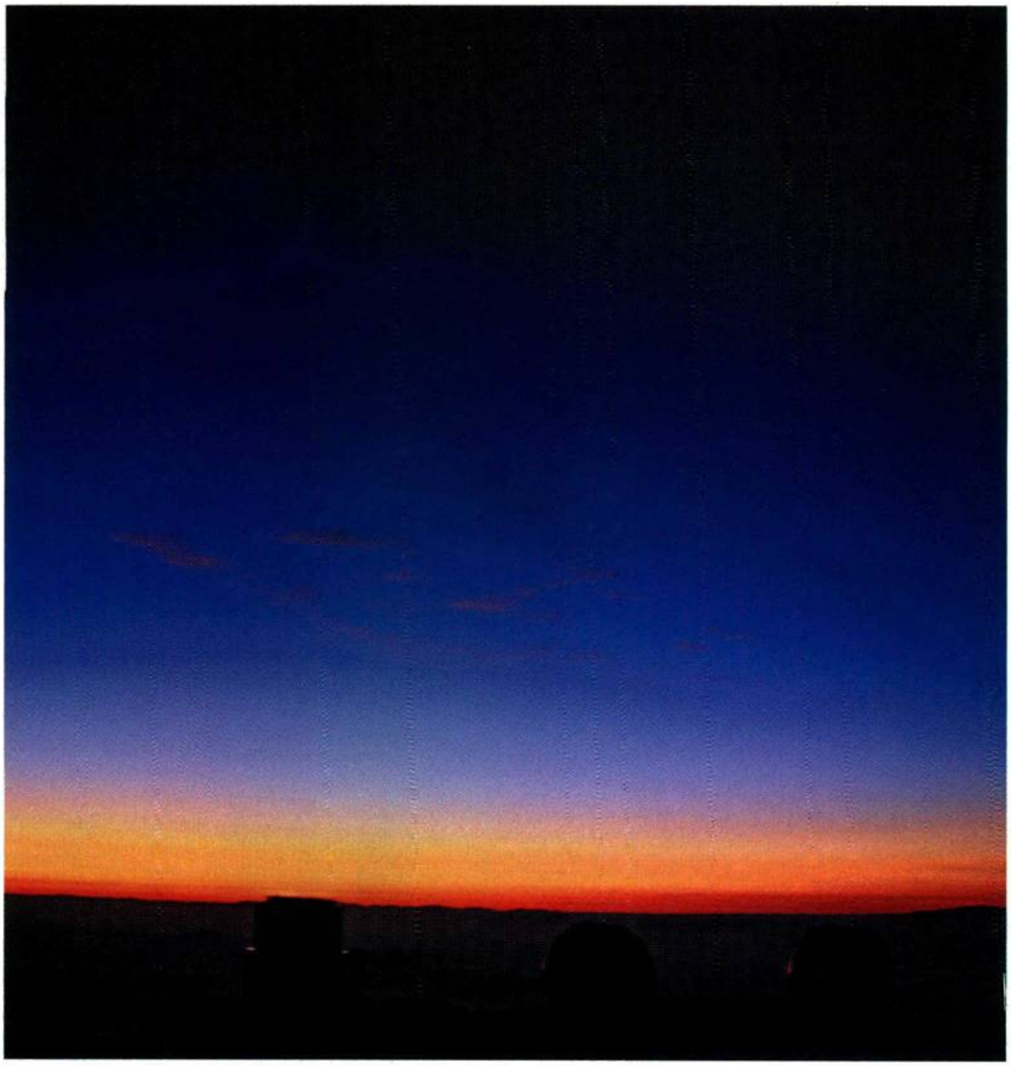


Sunset View from Mauna Kea

DAVID HANON

(35mm lens, Fuji Velvia film)

Moon, Venus, and 28 Sagittarii

ANTHONY GALVÁN III

(28mm lens at f/3.5, Fujicolor 100 film, 1-second exposure taken February 2, 2000)

PERSPECTIVES

View from the Top

Twilight on Mauna Kea can play tricks on the mind.

▶ It's amazing how the function we call vision can be fooled by a simple change of perspective. If you have reasonably dark skies, the misty late-summer arch of the Milky Way is instantly recognizable. How could it look like anything else? But a change in your point of view can trick your senses.

In May, our friends David Hanon and his wife, Linda, visited Sandra and I at our home near the Kona coast of Hawaii. They did lots of sightseeing, including an exciting evening trip to an active area of the Kilauea volcano. Finally, toward the end of their visit came the pilgrimage to the American "Mecca" of astronomy: an observing trip to Mauna Kea. David had agreed to share his expertise as an astroimager with me as I tried to make sense of my new CCD camera. With telescope, camera, and warm clothes piled into the Jeep, we made our way to about the 12,000-foot level of the mountain just as the sun was setting.

We quickly set up the scope. Then we just stood back and marveled as the sky darkened and the stars popped out. The seeing and transparency were exquisite. There was not a twinkle among the multitude of stars engraved on the dome of the sky. Omega Centauri was easy for the unaided eye and dazzling in the eyepiece. M51 was the best we had ever seen in a 10-inch telescope. And so it went for an hour or more, until the Go-To button was almost smoking. I really appreciate the technology that lets me look "at" objects instead of "for" them.

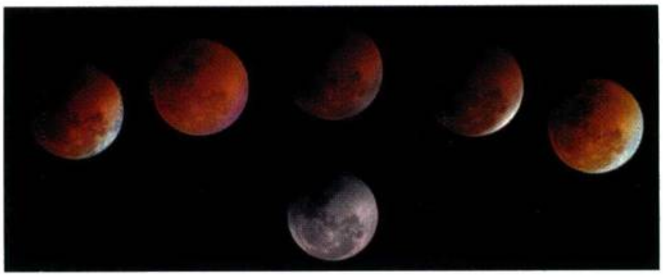
We tore ourselves away from the light show above and devoted ourselves to hooking up the CCD, derotator, and laptop. David has the patience of Job, but even he couldn't overcome my ineptness with the new toys. Quite a lot of time passed as we sat hunched over the keyboard, trying to get a decent image on the screen. Finally we decided to call it quits and go back to using our eyes alone. While I packed up the accessories, David stood back to scan the sky again. After a moment he said, "Looks like the clouds are coming in from Hilo."

"That's my kind of luck," I grumbled, not looking up.

A few minutes later he laughed and called me to take a look. Sure enough, there was a bank of clouds to the south and southeast. "Look again," he said. I did, and the clouds became the star clouds and rifts of the Milky Way rising parallel to the horizon.

Never before had we seen the sky meet Earth with such clarity. We saw what we thought we should see. Our minds had been tricked by a different point of view.

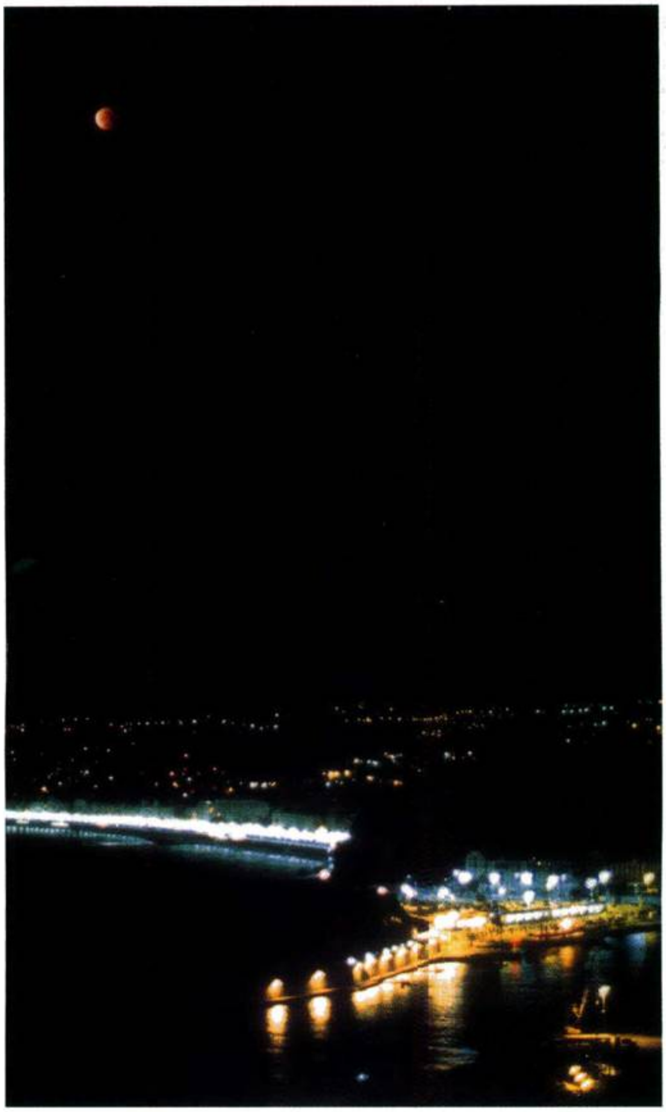
Terry Teets works for the Mauna Kea Visitor's Center and conducts public star parties there. He lives at the 1,000-foot level overlooking the Kohala coast and about a one-hour drive from the Mauna Kea summit.



Phases of a Lunar Eclipse

VIC AND JEN WINTER

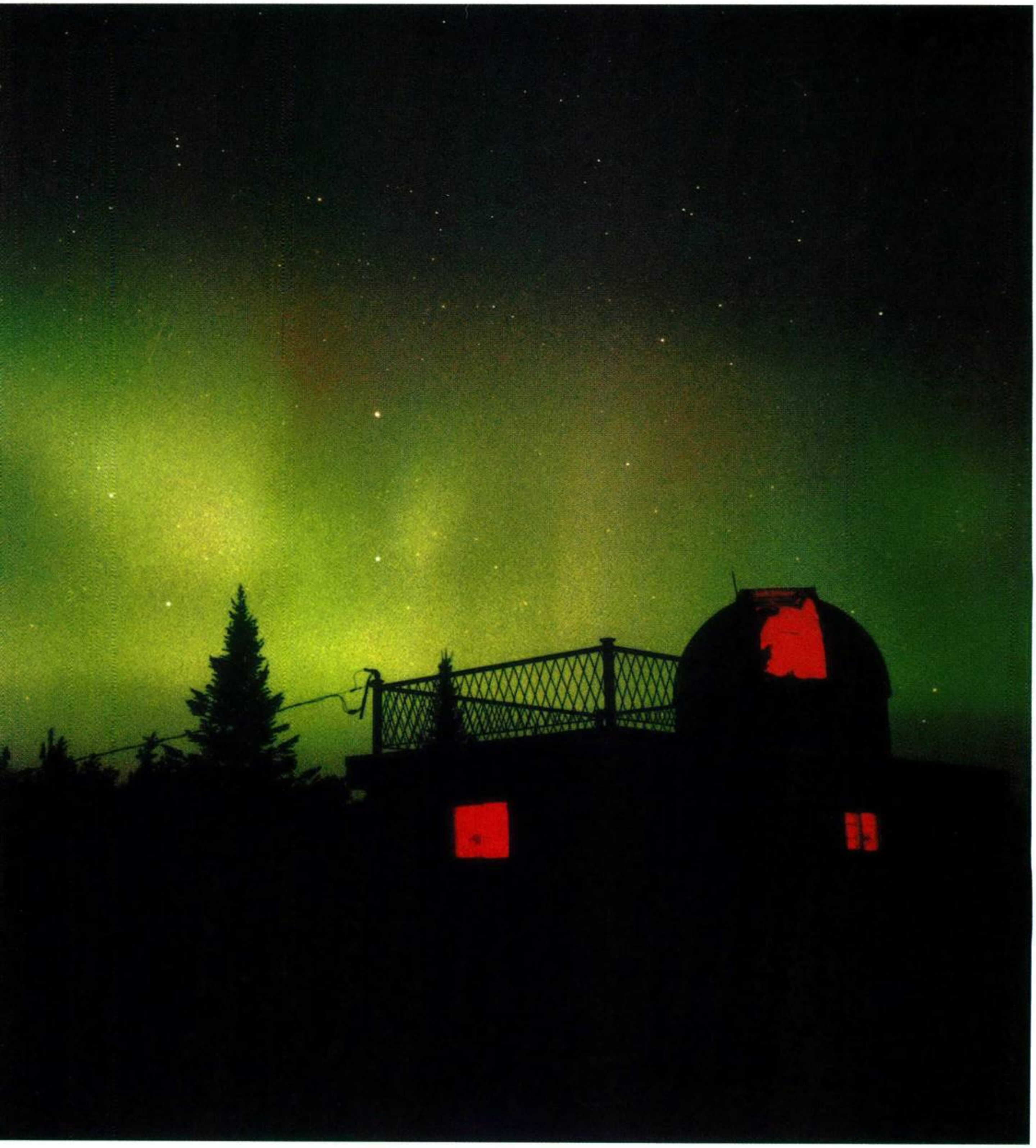
(5-inch f/10 SCT, Fuji color negative ISO 400 film, partial phases at 1/250-second exposures, totality at 8-second exposures, taken January 20–21, 2000)



Nice Totality

MICHEL BENVENUTO

(50mm lens at f/1.8, Fujichrome Provia 1600 ISO film, ⅛-second exposure taken January 21, 2000, from Nice, France)

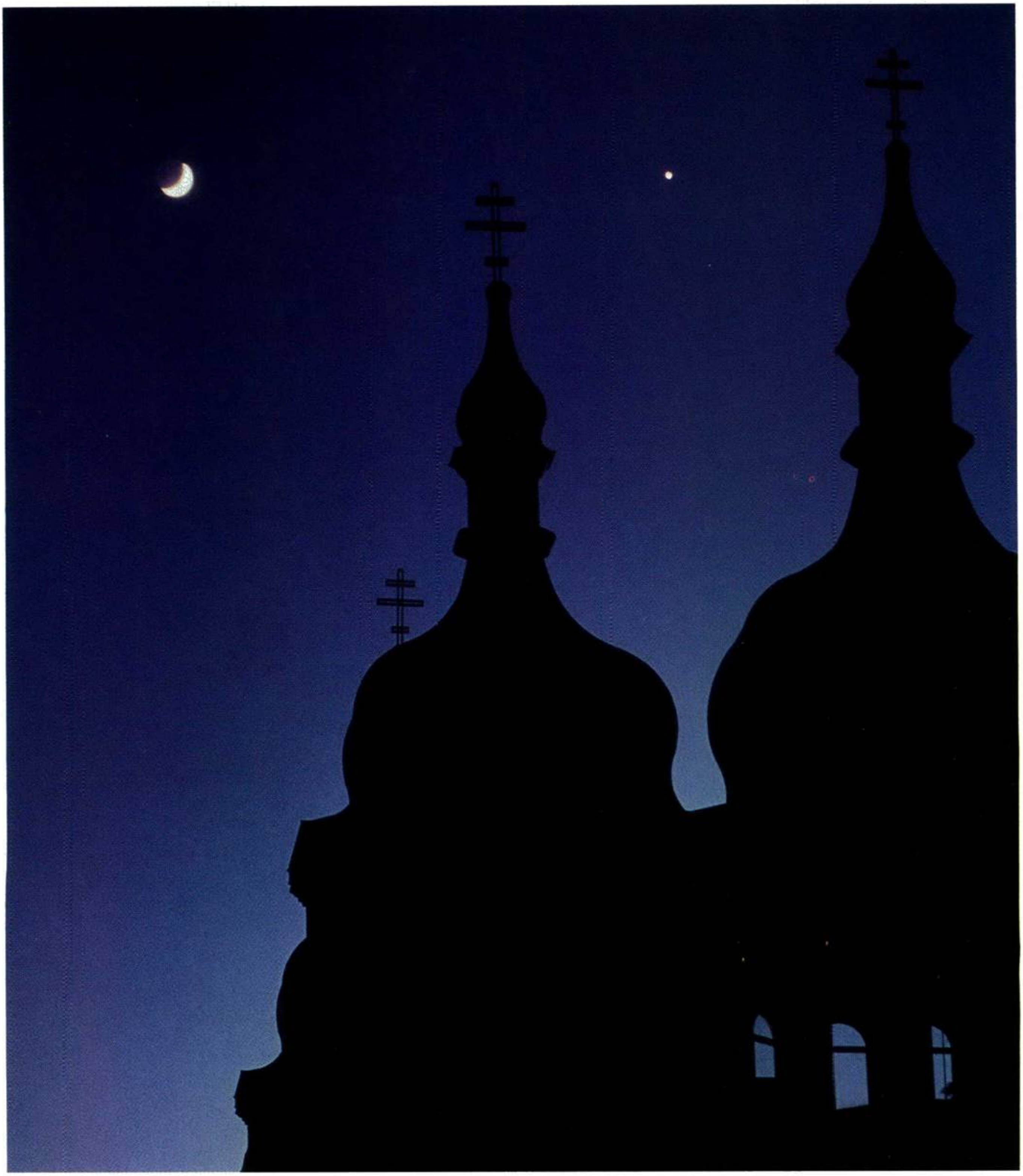


Aurora at Observatoire Alphonse-Tardif, St-Nérée, Quebec

DOMINIC CANTIN

(28mm lens at f/2.8, Fuji Superia 400 film, 25-second exposure taken September 13, 1999)

This month's best astrophoto



Venus Competes with the Moon's Earthshine

DENNIS ZERWAS JR.

(28mm lens at f/2.8, Elitechrome 200 film, 23-second exposure taken May 20, 1999, at Saint Katherine Ukranian Orthodox Church, Arden Hills, Minnesota)

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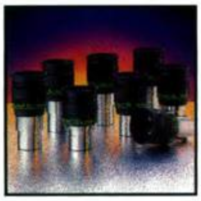
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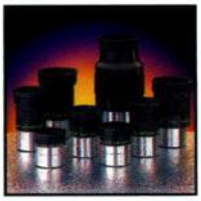
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Images by Jack Newton with the Meade 16" LX200 Schmidt-Cassegrain telescope, Meade f/6.3 Focal Reducer, Meade Pictor 1616XTE CCD Imaging Camera, and Meade 616 Color Filter System. *Clockwise from lower-left:* spiral galaxy (M83) in Hydra; nebulosity (NGC 1977) surrounding the star 42 Orionis; the Dumbbell Nebula (M27) in Vulpecula; detail of the Trapezium in the Orion Nebula (M42). Mr. Newton comments: "The combination of the blue-sensitive Pictor 1616XTE camera and the sharp spectral cut-offs of the Pictor 616 filters were essential to the success of this imaging series. Note the prominent H-II regions in M83 — regions rarely imaged even by professional telescopes."

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